GOVERNMENT OF JAMAICA

THE SECOND NATIONAL COMMUNICATION OF JAMAICA TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

JUNE 2011

EXECUTIVE SUMMARY

Jamaica acceded to the United Nations Framework Convention on Climate Change (UNFCCC) in 1995. Signatories to the Convention are requested to report periodically on their inventory of anthropogenic emissions and removals of greenhouse gases (GHGs) not controlled by the Montreal Protocol as well as details of the activities the Party has undertaken to implement the Convention.

Jamaica, which is a non-Annex I Party to the Convention, submitted its Initial National Communication (INC) in November 2000. The INC included a GHG inventory for the reference year 1994 in compliance with Articles 4 and 12 of the UNFCCC and prepared in accordance with the Intergovernmental Panel on Climate Change (IPCC) 1996 *Revised Guidelines for Preparation of National GHG Inventories*. The INC also included vulnerability and adaptation assessments for the agriculture, water, and coastal zone sectors.

This Second National Communication (SNC) includes GHG inventories for 2000-05 (and reference year 2000), prepared using the updated 2006 IPCC inventory guidelines. The SNC also assesses climate change impacts for the key sectors of health, human settlements, and tourism, in addition to revisiting agriculture, water, and coastal zones, for the years 2015, 2030, and 2050. Although not required as a non-Annex I Party, Jamaica's SNC also includes an assessment of potential mitigation options to reduce GHG emissions over 2009 to 2030 that will, just as importantly, improve energy efficiency. Finally, other activities in support of the Convention, such as awareness raising, a review of the national systematic observation systems, and a technology needs assessment, are also described.

The SNC was undertaken by the Ministry of Local Government and the Environment and Disaster Management Unit on behalf of the Meteorological Service of Jamaica, which has the responsibility for the completion and submission of the SNC.

National circumstances

Jamaica is a Small Island Developing (SID) State. An island nation in the Caribbean Sea, it is part of the group of islands known as the Greater Antilles that also includes Cuba, Puerto Rico, and Hispaniola. Jamaica was discovered by Christopher Columbus in 1494. At that time, it was inhabited by Arawakan-speaking Taino Indians, who had named it Xaymaca, which means the "Land of Wood and Water" or the "Land of Springs". Upon possession by the Spanish, it became known as Santiago and then Jamaica after it was possessed by the British in 1655. Jamaica achieved full independence in 1962.

Jamaica is the third most populous Anglophone country in the Americas after the USA and Canada. As of 2007, Jamaica had a resident population of 2,682,100 (representing end of year population). Life expectancy has averaged 72.1 years since 2000 but is trending up. Improved health care is a key factor. Although a developing country, Jamaica has made considerable strides over the past three decades with regard to health care, especially so for women. The literacy rate is high – in 2007 it was estimated to be 86 percent, above the world average of 82 percent. The incidence of poverty has also undergone significant decline, falling from 18.7 percent in 2000 to 14.3 percent in 2006. There is a clear relationship between rural locations and higher incidences of poverty. Over 60 percent of the poor are in rural areas, compared with an average 14-20 percent in the Kingston Metropolitan Area.

Approximately 52 percent of the population lived in urban areas in 2001 – an increase of almost 12 percent since 1970. Most Jamaicans (78 percent) live in separate/detached housing. As of 2006, approximately 68 percent of homes had piped water, 65 percent had flush toilets and 33 percent pit latrines, and 90 percent had electrical lighting.

Jamaica operates a mixed economic system; where there are prominent state enterprises alongside a viable private sector. The major sectors of the Jamaican economy are bauxite, tourism, agriculture, and manufacturing, with tourism and mining being the leading foreign exchange earners. The economy had an annual size (in terms of GDP) of approximately J$250 billion in 2007 (Figure 1.3). From 2000-07, the country averaged real growth of 1.5 per cent per annum, ranging from 0.8 per cent in 2000 to 2.5 per cent in 2006 (Figure 1.3).

The economy has become more service driven over time – presently (2007) 34.2 percent of the economy can be seen as the goods sector and 72.9 percent as the service sector, while in 1992, 42.6 percent of the economy was goods and 39.7 percent in 2000. The national unemployment rate averages 11.4 percent and has been showing a marginal downward trend since 2000. Female unemployment is markedly higher than male unemployment – at 14.5 percent vs. 6.2 percent respectively in 2007.

Geography and climate

At approximately 2000 square miles, Jamaica is the third largest island in the Caribbean. The island is approximately 230 km long, oriented in an east-west axis and is approximately 80 km at its widest point. Land area is 10,990 sq. Km, of which about 160 sq. km is water and the coastline is approximately 1,022 km. The terrain is characterised by a mountainous region along the island's east west axis and narrow coastal plains. The highest elevation is Blue Mountain Peak which is 2,256 m above sea level. Most major towns and cities are located on the coast, with its chief towns and cities being the capital Kingston, Montego Bay (its second city), Mandeville, Spanish Town, Ocho Rios, and Pt Antonio. Only two major parish capitals are located inland.

The local climate is deemed tropical, with coastal areas having hot and humid weather and inland areas having a more temperate climate. Jamaica lies in the hurricane belt of the Atlantic Ocean which historically has been evidenced by strong tropical hurricanes. The more recent ones, Hurricanes Dean (2007) and Ivan (2004), have created huge infrastructural damages and some loss of life.

Jamaica's freshwater resources come from surface sources (rivers and streams) and underground sources (wells and springs) and rainwater harvesting. Groundwater supplies most water demands (approximately 80 percent of production) and represents 84 percent of the island's exploitable water. The island's water sources are associated with major rock formations and their interrelationships.

The National Greenhouse Inventory

For the INC, the base year for the national GHG inventory was 1994. For the SNC, the base year is 2000, and the national inventory was prepared for 2000-05 using the IPCC 2006 Guidelines and IPCC good practice guidance manuals. The gases included in the inventory are the direct GHGs: namely, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6), and the indirect GHGs: non-methane volatile organic compounds (NMVOC), carbon monoxide (CO), nitrogen oxide (NOx), and sulphur dioxide (SO_2).

GHG emissions were estimated for sources and sinks in four sectors:

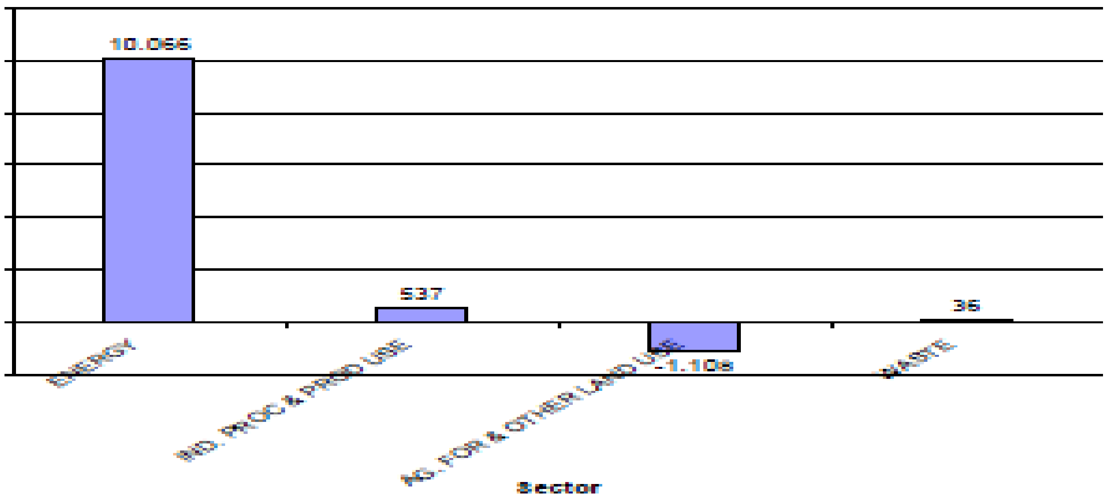
- Energy;
- Industrial Processes and Product Use;
- Agriculture, Forestry and Other Land Use; and
- Waste.

The lack of a complete archive of data for the 1994 inventory precluded recalculation of the 1994 inventory using the *2006* IPCC Guidelines. The investigation of apparent anomalies in estimates of the carbon dioxide sink in the forestry sector and methane emissions from soils in the 1994 estimates were also not possible.

Key Results

The net **carbon dioxide** emissions increased from 8,418 Giga-grams (Gg) in 1994 to 9,532 Gg in 2000. The energy sector accounted for nearly 86 percent of the 2000, carbon dioxide emissions in 2000, down from 97 percent in 1994. The total estimated carbon dioxide removals (sinks) increased from 167 Gg in 1994 to 1,108 Gg in 2000. However, there was insufficient data available to determine the reasons for the large change – an apparent discrepancy. The Agriculture, Forestry and Other Land-Use sectors were responsible for the sink. Figure 1 shows the carbon dioxide emissions by sector for Jamaica in 2000.

Figure 1: Carbon Dioxide Emissions, by sector, in Jamaica (2000)



Methane emissions in 1994 were estimated at 58.5 Gg and 34.7 Gg in 2000. The 2000 estimates for methane emissions from enteric fermentation (36 Gg) and manure management (7 Gg) were considerably higher than those in 1994 (8.17 Gg and 0.646 Gg respectively). The waste sector accounted for 54 percent of methane emissions in 2000, followed by Agriculture, Forestry and Other Land Uses (26%) and Energy (20%) (See Figure 2).

Nitrous oxide emissions fell from 344 Gg in 1994 to 11.7 Gg in 2000. The reason for the large discrepancy between the 1994 and 2000 estimates could not be determined since raw data used in the calculations for 1994 were not available. Managed soils (fertilizer applications) accounted for 80 percent of the nitrous oxide emissions (Figure 3).

Figure 2: Methane Emissions, by sector, in Jamaica (2000)

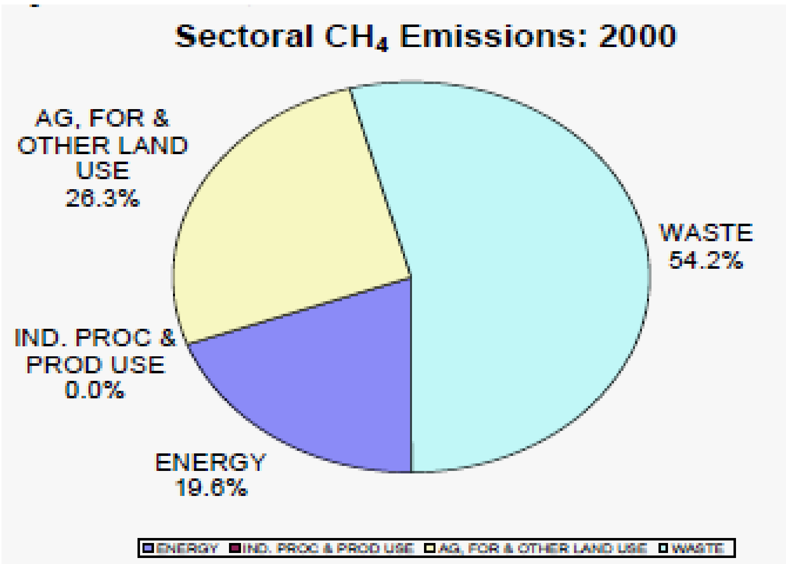
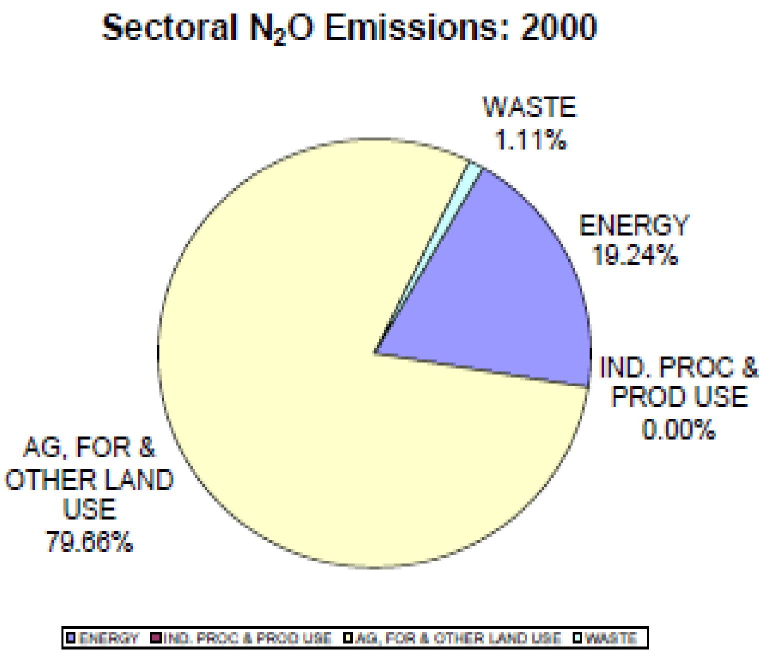


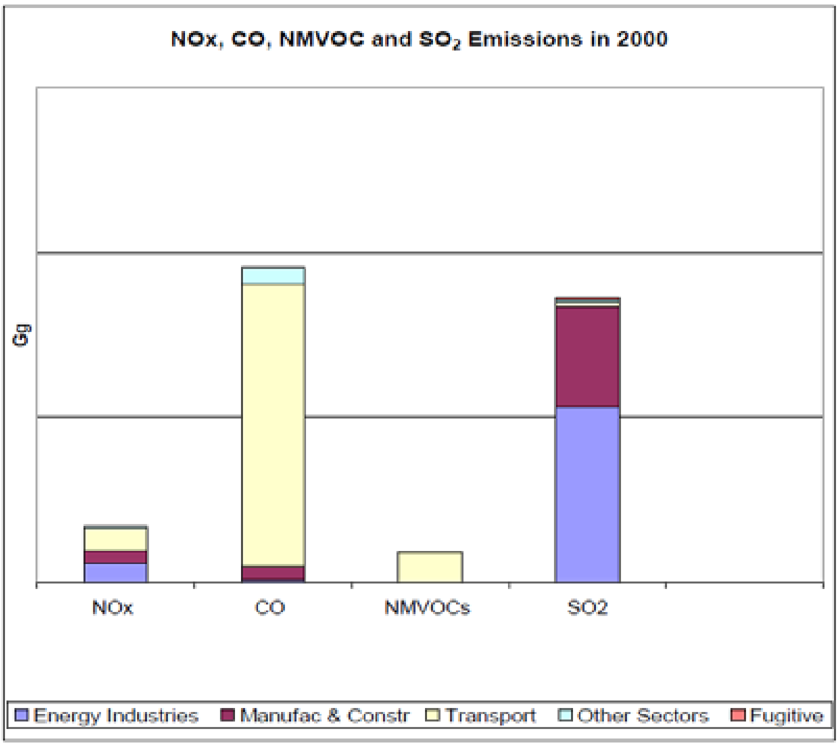
Figure 3: Nitrous Oxide Emissions, by sector, in Jamaica (2000)



Estimates for **hydrofluorocarbons** emissions were not made in 1994 but were 5.16 Gg in carbon dioxide equivalent in 2000.

With respect to **indirect GHGs**, nitrogen oxide emissions were estimated at 30.9 Gg in 1994 and 35.9 Gg in 2000. Carbon monoxide, non-methane volatile organic compounds and sulphur dioxide emissions in 1994 were 173 Gg, 29.1 Gg and 98.9 Gg respectively; these rose to 205 Gg, 27.6 Gg, and 173 Gg respectively in 2000. The transport sector accounted for the majority of carbon monoxide and non-methane volatile organic compounds emissions; the energy industries (electricity generation) and manufacturing categories accounted for the majority of sulphur dioxide emissions. The emissions of the indirect GHGs for 2000 are shown in Figure 4.

Figure 4: Emissions of Indirect Greenhouse Gases in Jamaica (2000)



Some sub-sectoral contributions to the 2000 GHG inventory emissions are worth noting:

- Manufacturing and construction accounted for 35.7 percent of net carbon dioxide fuel combustion emissions, followed by energy industries (electricity generation and petroleum refining) at 33.1 percent, and transport at 24.2 percent. Manufacturing and construction includes some (but not all) components of the bauxite alumina industry.
- In the transport sector, light duty gasoline vehicles accounted for 48 percent of the carbon dioxide emissions, with light duty gasoline trucks, heavy duty diesel vehicles and heavy duty gasoline vehicles each contributing around 15 to 18 percent emissions.
- Methane emissions in the waste sector were mainly from solid waste disposal (71%) followed by wastewater treatment (26%).

GHG Emission Trends between 2000 and 2005

Overall, annual emissions for carbon dioxide, methane and nitrous oxide are shown in Figure 5. Carbon dioxide emissions increased consistently from 9,531 Gg in 2000 to 13,956 Gg in 2005, apart from a slight dip in 2004. There was a similar trend for methane emissions, which rose from 31.1 Gg in 2000 to 41.9 Gg in 2005. Nitrous oxide emissions trended up, but in much smaller quantities.

The large increase (46%) in carbon dioxide emissions was due to increases in energy sector fuel consumption in the manufacturing (bauxite and alumina industry) and transportation categories (Figure 6). There was little change in the magnitudes of the sources and sinks for carbon dioxide in the Agriculture, Forestry and Other Land Use sectors over 2000-05. In the Industrial Processes and Products Use Sector, carbon dioxide emissions from the cement industry increased over 2000-05, but those due to lime manufacture declined. Importation of lime was required to meet the alumina industry demands. Carbon dioxide emissions in the waste sector increased over 2000-05, but the contribution from managed disposal sites decreased while that from unmanaged sites increased. (There was a similar pattern for methane emissions in the waste sector; with those from managed sites decreasing and those from unmanaged sites increasing.)

Figure 5 CO2, N2O and CH4 Emissions: 2000-2005

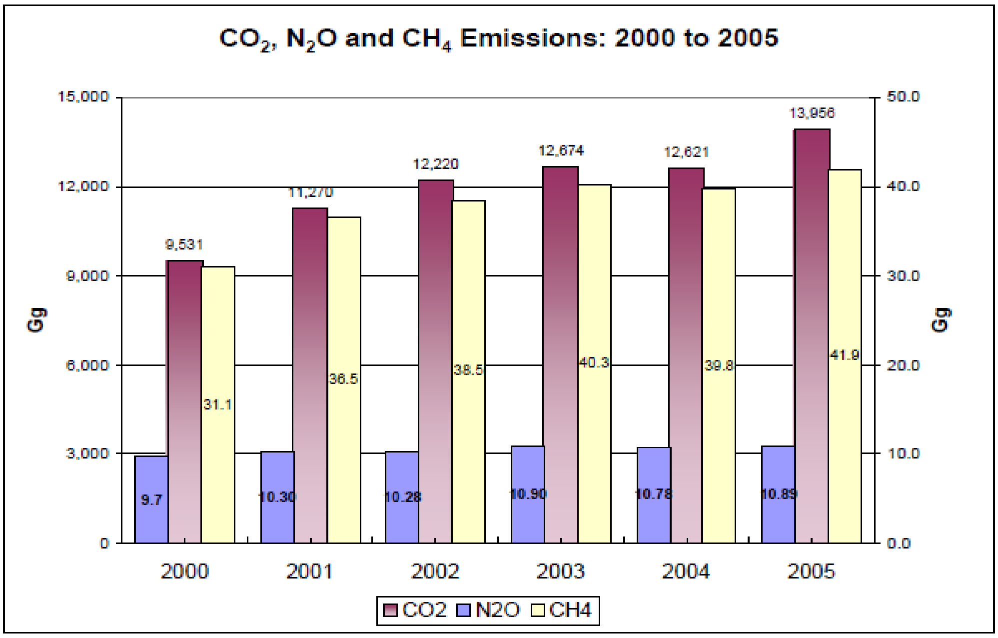
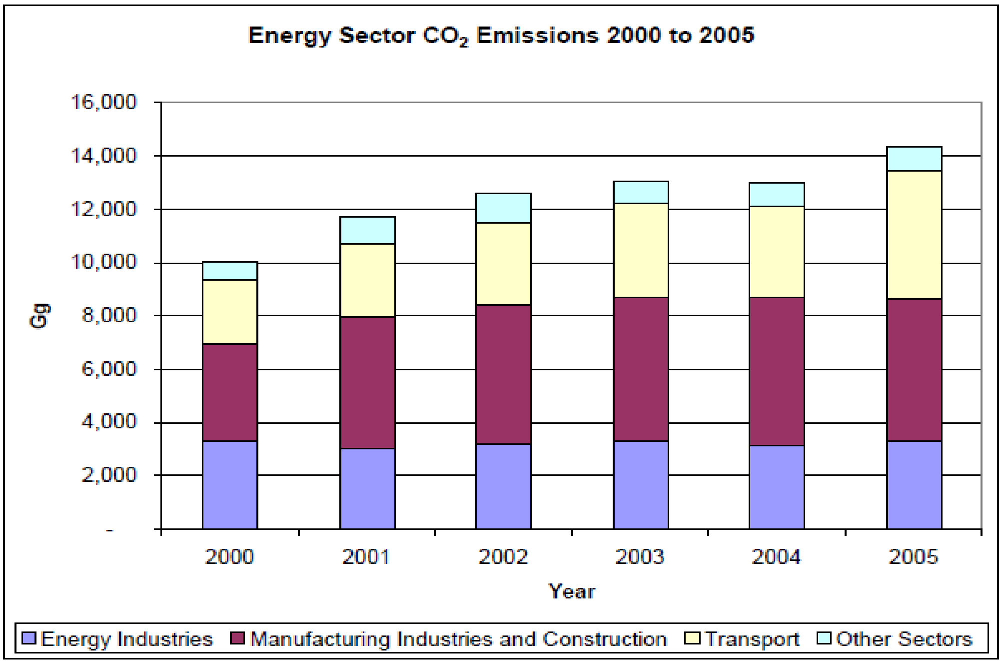


Figure 6: Energy Sector CO2 Emissions: 2000 – 2005



Programmes Containing Measures to Facilitate Mitigation of Climate Change

For some countries, particularly developed countries with emission reduction targets, energy policy is linked to or framed within the context of climate change mitigation and the move towards a low carbon economy. Although developing countries, including Jamaica, do not have emission reduction targets, “no regrets” mitigation actions such as energy conservation and development of renewable energy sources can have positive impacts in terms of economic, social, and environmental considerations.

Jamaica has no known primary petroleum or coal reserves and imports all of its petroleum and coal requirements. Domestic energy needs are met by burning petroleum products and coal and renewable fuel biomass (i.e., bagasse, fuel wood, and charcoal) and using other renewable resources (e.g., solar, wind and hydro). In 2008, approximately 86 percent of the energy mix was imported petroleum, with the remainder coming from renewables and coal. Electricity is generated primarily by oil-fired steam, engine driven, and gas turbine units. Smaller amounts of electricity are generated by hydroelectric and wind power. Use of solar energy is negligible.

Jamaica’s Petrojam refinery, which has a nameplate capacity of 35,000 barrels per stream day (bsd), provides some of the refined petroleum products and the remainder is imported. Petrojam is a state-owned enterprise and the associated electric utility – the Jamaica Public Service Company Limited (JPS) – is 80.1 percent privately owned and the remainder government owned. JPS is the sole distributor of electricity to the public and it generates the majority of the electricity sold to the public. The remainder is purchased from independent privately owned power producers. A small amount of electricity is generated by industrial, commercial or residential operators for their own use. Heavy fuel oil needed by the bauxite alumina industry is imported directly by the industry.

The bauxite and alumina industry has the largest percentage of end use, which was 37.4 percent in 2008, followed by electricity generation (25%), transport (20.4%) and the sugar industry (12.2%).

The Long-Range Energy Alternatives Planning System (LEAP) model was used for the mitigation assessment to examine the effects of three scenarios on demand, transformation, resources, and non-energy sector emissions. LEAP is a scenario-based, energy-environment modelling tool based on a comprehensive accounting of how energy is consumed, converted and produced in a given region or economy under a range of alternative assumptions.

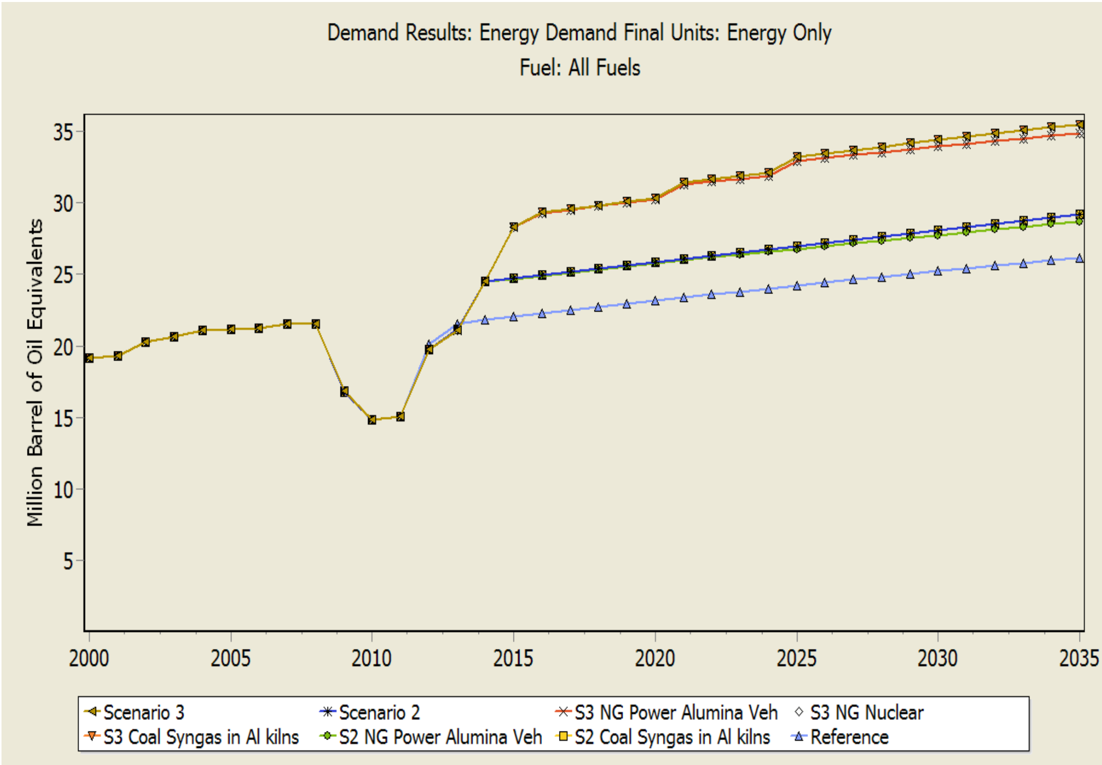
The base year used in the analysis was 2000 – the same year used for compilation of the national GHG emission inventory. Historical data from 2000-08 were used and projections were made for 2009 to 2035 for three groups of scenarios (the **Reference Scenario, Scenario 2** (S2) and **Scenario 3** (S3)), which were characterised primarily by different rates of growth for the population and GDP.

The Reference Scenario is linked to Jamaica's Vision 2030 GDP and population growth targets, and does not include any initiatives to mitigate GHG emissions. The Reference Scenario assumes that two of three alumina refineries that closed in 2009 would reopen. It also assumes that the Petrojam Refinery upgrade would be completed in 2014 and provides low sulphur diesel and gasoline for the vehicle fleet and petcoke for a 100 MW plant at Hunts Bay. Finally, the Reference Scenario also assumed the use of coal at the new old Harbour power station.

Scenarios S2 and S3 include the same assumptions on the alumina and Petrojam refineries as well as progressively higher GDP growth rates but lower population growth rates. The mitigation options in S2 and S3 draw from Jamaica's newly adopted 2009-30 energy policy, including one option for use of nuclear power in S3. Future energy intensity data used in the scenarios was based on existing and proposed voluntary energy standards for appliances used in US and/or Canadian Energy Star programmes, but with later implementation or penetration for Jamaica. Import data for various appliances and the typical and maximum lifetimes of appliances together with policy initiatives were taken into consideration in estimating the penetration of energy efficient appliances in S2 and S3.

The final energy demand for all scenarios, as modelled with LEAP, is shown in Figure 7. The most striking feature is the dramatic decline in energy demand in 2009 through 2012 as a consequence of the closure of three alumina plants in the first quarter of 2009 and the (assumed) reopening of two of those plants in 2011 with full production achieved in 2012. The final energy demand is not very dependent on the choice of fuel in the S2 and S3 scenario options and the demand under the S2 options are lower than those under the S3 options. The large increase in energy demand in the S3 options is due mainly to a new alumina plant and, to a lesser extent, on lower population growth and the associated demands for electricity and an increase in cement production.

Figure 7: Final Energy Demand Projections for Jamaica, All Scenarios (2009-35)



In terms of overall demand, the percentage change in carbon dioxide emissions for 2035 relative to 2000 increased by 29 percent, 52 percent, and 98 percent for the reference, S2, and S3 scenarios respectively. This is consistent with the general increase in carbon dioxide-generating (and energy consuming) activities due to increases in population, number of vehicles, and bauxite and alumina production. The scenarios all entailed additional coal fired electricity generation whose emissions easily outweighed the emission reductions from much smaller additions of wind and hydro generating stations. The major mitigation measure was the introduction of natural gas (scenarios *S2*NG and *S3*NG) and a nuclear plant in conjunction with natural gas (scenario *S3*NGNU). Because of these measures, the carbon dioxide emissions in these scenarios are lower than those in the corresponding *S2* and *S3* scenarios.

Successful implementation of the mitigation measures will *inter alia* depend on:

- Provision of incentives/disincentives for the development and use of innovative technologies that improve/worsen efficiency;
- Implementation of energy related policies that support the goals of the national energy policy, namely, the biofuels, waste-to-energy, and carbon emissions trading policies;
- Creation of relevant legislation to support investments in efficiency in energy-intensive sectors such as transport and bauxite;
- A review of previous and existing demand side management programmes for performance, strengths and lessons learned;
- Stronger institutional capacities in the energy and environment sectors, in particular carbon trading;
- Development of programmes designed to influence market behaviour towards more efficient use in energy across all sectors;

- Development of mechanisms to efficiently share energy related information and for public and private sector entities to collaborate on energy related projects;
- Establishment of a system to identify and replace old inefficient electricity equipment and (especially) generating units/plants with more fuel efficient and cost efficient technologies and plants;
- Promotion of strategic partnerships between the public and private sectors to finance and develop energy diversification projects; and
- Introduction of national vehicle emission standards and regulations to reduce vehicular emissions and promote introduction of cleaner transportation fuels (especially CNG).

Programmes Containing Measures to Facilitate Adaptation to Climate Change

Vulnerability and adaptation assessments were undertaken for five sectors: water resources, agriculture, human health, coastal zones and human settlements, and tourism.

Existing & Future Climate in the Caribbean and Jamaica

The annual average rainfall in Jamaica is 1,871 mm based on data from the National Meteorological Service for1981-07. While there are no discernable long-term trends, the maximum level of consecutive dry days is increasing and the number of heavy rain days is increasing. While there are variations in tropical and extra-tropical cyclone activities, such as hurricanes and typhoons, daily temperatures are at an average of 26.2° Celsius to 30.0° Celsius over coastal areas. According to the 2007 IPCC 4th Assessment Report, warming ranged from 0.0° Celsius to 0.5° Celsius per decade, globally.

This gives rise to the following four emission ranking scenarios:

1. A1 – More integrated sub-groups, economic growth and liberal globalisation
2. A2 – More divided world, economic growth with greater regional focus
3. B1 – Integrated, environmentally sensitive with strong global relationships
4. B2 – More divided but environmentally sensitive with high regional focus

Various models were used to assess future climate projections, including the AOGCM (HAD, EHC, MRI models) and RCM (PRECIS). There is an indication of consistent temperature warming across all seasons and scenarios. The projected 1.5°-2.0° Celsius increase in temperature results in increased evaporation losses, decreased precipitation, and a continuation of rainfall decline.

Water Resources

As noted earlier, groundwater supplies most water demands in Jamaica (approximately 80% of production) and represents 84 percent of the island's exploitable water. The island's water sources are associated with major rock formations and their interrelationships. The island is divided into ten hydrological basins.

Stream flow data from the Jamaican Water Resources Authority indicate that several rivers are in deficit, which results in water lock offs and an overall limit in water supply. The Hope River, Rio Cobre, and Rio Minho areas are under stress. It is not clear whether Jamaica has enough storage to provide water supplies to adequately meet all demands during periods of below average rainfall. The monitoring of wells need some improvements so that the real trends may be better identified. Additionally, more work need to be done with data collection to make it more relevant to user needs.

However, initial analysis of the Kingston Metropolitan Region, including the communities in South-eastern St. Catherine, indicates that increased abstraction in the upper Rio Cobre basin could be the main cause of lower water supplies and not so much as a direct result of less rainfall. The Hope River – another major source of water resources – is likely to decline by 11 percent by 2030. Significant issues associated with water resources management and vulnerability and the impacts of climate change are likely to present some pressure.

Proposed Elements of a Water Resources Adaptation Strategy for Jamaica

1. Increasing and maintaining investment in hydrological monitoring and water use through a national database. This will result in improved data collection and storage on a national scale.
2. Funding research into adopting a water resources and water supply planning method under climate change. With appropriate methods in place, consistent regional and national planning can take place under a changing climate.
3. Developing appropriate modelling tools to assist strategic planning of water resources. There is an urgent need to develop a consistent set of appropriate modelling approaches and tools.
4. Investigate shifting focus from ground water to surface water storage for water supply. Reducing the reliance on vulnerable coastal aquifers, in terms of quality and quantity with the increased use of surface water reservoirs to maintain supplies.

Agriculture

Agriculture remains central to the Jamaican economy for employment and foreign exchange earnings. Nonetheless, the agriculture sector has been consistently declining over the past two decades. In 1943, 45 percent of the population earned their living from agriculture; by 2006, this had declined to 17.9 percent. Agriculture's contribution to GDP was 5.3 per cent in 2005, compared to 6.5 per cent in 2000.

Already there are signs of significant vulnerability of the sector to climate variability (e.g., storms and droughts). In September 2004, Hurricane Ivan destroyed the entire domestic and export crop resulting in 8,000 persons being out of work. Forty-five percent of coffee berries were lost and sugar cane was uprooted, resulting in reduced sugar content and yield. Livestock was also affected as milk production decreased due to the death of animals. Studies from elsewhere indicate that vulnerability will increase in the future with climate change. However, it is difficult to determine the impact of climate change on agriculture and develop appropriate adaptation measures without the appropriate tools and approaches.

Proposed Elements of an Agriculture Adaptation Strategy for Jamaica

1. Raise awareness of the potential impact of climate change on the agricultural sector. Climate change is not mentioned in the Agricultural Development Strategy 2005-2008.
2. Develop modelling approaches and tools to allow assessment of impacts of climate change on export and domestic crops and meat production. Detailed crop/country/climate specific assessments are required to inform an adaptation programme and policy development.

3. Develop regional links to fund and promote plant breeding programmes for common crops. Adaptation strategies include the development of crop varieties with increased temperature, drought and pest resistance.
4. Review approaches to integrated pest management under climate change. Existing pest management strategies may require modification under climate change. Care must be taken that any changes to these strategies do not have negative impacts on the environment, for example, from increased pesticide use.

Human Health

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 hemorrhagic 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 shell-fish 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 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.

<u>Proposed Elements of an Health Adaptation Strategy for Jamaica</u>

Climate change must also be mainstreamed into the health system to recognise the likely impact of vector-borne diseases. Under-financing is a major problem that can affected staff training and the ability to conduct surveillance.

Climate change should be included in the mandate of Office of Disaster Preparedness and Emergency Management (ODPEM) since extremes in climate change can lead to greater incidences of flooding and storm surges. The Agency should be aware of this as well as the possibility of Category 5 hurricane occurring more frequently. Other adaptation strategies included the proper identification and upgrading of shelters to meet the demands for the outbreaks of diarrhoeal diseases, injuries and lacerations resulting from flying and broken objects, pre-existing conditions such as foot ulcers and other unhygienic conditions that may be worsened.

Short-term adaptation strategies for addressing vector-borne diseases include:

- Public education aimed at encouraging individuals to identify and eliminate current breeding sites and the symptoms of dengue;
- Surveillance in outbreak communities for the purpose of environmental sanitisation; and
- Adult mosquito control through the use of appropriate insecticide.

Overall recommendations for the health sector include:

- Public education in the management of stress;
- Elimination of taxes on electric fans;
- Increased public education in the areas of sanitation and food poisoning;
- Relevant agencies prepared for handling increases in the incidents of food poisoning;
- Public health inspections for mosquitoes, including pest and rodent eradication;
- Sustainable design standards for housing in areas subjected to high rainfall and hurricane winds, for example, roofs can reduce heat absorption by painting them white or silver; windows need cross ventilation; and
- More attention to be paid to the design of settlements.

Priority should be given to:

- Better water monitoring and management through improvements at the National Water Commission and Water Resources Authority;
- Improving the capabilities of ODPEM to warn of hazards;
- Improving data gathering ability and technical support staff of the Meteorological Office for monitoring and warning of air-boned type diseases;
- More collaboration between research institutions involved in pollution control;
- All available climate data from sources are to be used to validate regional models and calibrate statistical models;
- Support should be given to research institutions involved in environmental related health risks to run as many regional and statistical downscaling models as possible for calibration and inter-comparison purposes;

- Safe water storage drums; and
- More proactive actions in pressing the case for mitigation of greenhouse gases, especially by the developed countries, in order to prevent increased temperatures.

Coastal Resources and Human Settlements

The expected effects on the coastal zone of Jamaica from climate change, including possible future changes in sea-level, were assessed for five contrasting coastal areas: St. Margaret's Bay, Portland; the St. James Parish coastline east of Montego Bay; Long Bay, Negril; the coast from West End to Little Bay, Westmoreland; and Portmore, St. Catherine.

For estimating future sea-levels, it was assumed that the globally averaged rises projected by the 2007 IPCC Fourth Assessment Report applied to Jamaica. Various scenarios projected a rise by 2100 from a low of 0.18m to a high of 0.59m. For comparison, another set of values was compiled from a research paper that suggested the possibility of sea-level rise up to 1.6m by the end of the century.

Sea-surface temperature projections were taken from Caribbean data that suggested a temperature rise of about 1 degree Celsius by 2050. Figures for increased acidity were taken from 2007 IPCC Fourth Assessment Report, suggesting average global ocean surface pH reductions of 0.14 to 0.35 units. Baseline data from the Jamaican region have not yet been collected.

Although it is generally agreed that the incidence of severe and wetter hurricanes will probably increase, there is controversy over the likelihood of a general increase in hurricane frequency. Thus, it was assumed that there would be no increase in hurricane frequency or severity over the rest of the century.

The impacts of these processes on the various kinds of coastline around Jamaica were assessed. On beaches, short term erosion is largely governed by the incidence of storms. Over longer periods, sea-level rise will cause progressive retreat. Hard engineered structures such as sea-walls will probably lead to eventual disappearance of any beaches in front of them. Offshore breakwaters will be more useful in retaining near-shore sand supplies. On cliffs and rocky coasts, sea-level rise will bring the cliff top closer to sea-level and increase the frequency of overtopping of the cliff by storm waves and rock debris, including large boulders. Recession will be greatest for soft-rock cliffs, whereas fractured hard rock cliffs will be more prone to sudden collapse, as indicated in the included Jamaican examples. Wetlands present a particular problem due to their proximity to sea-level and the micro-tidal regime around Jamaica. Small changes in sea-level will prompt progressive retreat and migration of wetland eco-zones, unless vertical accumulation rates of wetland debris keep up with sea-level rise. Most Jamaican wetlands are fronted by a narrow beach which will retreat over the wetland, driven by storms and sea-level rise. No data on the vertical accumulation rate of wetland sediments is available for Jamaica.

These impacts are likely to be exacerbated, and even overshadowed, by non-climate change factors, such as deforestation, increasing riverine floods from destruction of forest and from poor farming practices, leading to increased near-shore sedimentation and turbidity, increased chemical pollutants from agriculture and industrial wastes, and from increasing coastal population growth.

A semi-quantitative Index of Coastal Vulnerability (CVI) to Sea-Level Rise, derived from one used by the United States Geological Survey for National Parks, was applied to the five study areas. The index indicated that Portmore and Long Bay Negril are relatively highly vulnerable to sea-level rise; the St.

James coast and St. Margaret's Bay are moderately vulnerable, while the West End to Little Bay coast has relatively low vulnerability.

An estimate of vulnerability to storm surge from hurricanes was carried out for the St. James coast and for Portmore, based on previously modelled estimates of return periods for surges. Projected sea-level elevations for 2015, 2030 and 2050 and elevations of 1.6m and 2m above sea-level were used. Using the sea-level projections derived from 2007 IPCC Fourth Assessment Report, these suggest that, for St. James, a surge height with an approximate return period of 3.5 to 4 years might be expected to flood a structure presently at 0.5m above sea-level. By 2050, due to sea-level rise, this structure would suffer surge inundation about every 2 years – in other words, the frequency of flooding by surge would be almost doubled. A structure at Portmore, located 0.5m above sea level, presently at risk of flooding by an event with a return period of 5.5 years, would be impacted by surge flooding about every 3.5 years by 2050. Figures are also estimated, for comparison, for other projections of future sea-level.

Proposed Elements of an Coastal Zones & Human Settlements Adaptation Strategy for Jamaica

The most important measure for adapting to sea-level rise involves a thorough revision of the present published setback guidelines. Instead of being based on slope angles, these should be related to the local risk of inundation from present and future storm events (i.e., site specific). Setbacks for structures on rocky coasts where there is storm-deposited debris should be determined by the position of the debris ridge formed by sandy and rocky debris accumulated over the past four millennia. Destroying this ridge for construction materials exposes communities and buildings behind the ridge to increased vulnerability from inundation and damage from moving debris.

The vulnerability of communities such as Portmore to extreme weather events and the susceptibility of escape roads to flooding require a major effort to re-engineer the Mandela Highway and other arterial roads at low elevation as all-weather highways.

In heavily populated and touristic areas of the coastline, there is a need to provide rapid dissemination of warnings of sudden events, perhaps aided by the development of audible warning systems. Such events would include tsunami (rare events, but with increasing impact on coastal structures as sea-level rises), flash floods, accidental release of poisonous gases, oil spills etc.

There will be an increasing need for beach nourishment projects for carbonate beaches. If the tourist industry is to survive through 2050, despite sea-level rise, increased ocean acidity and sea-surface temperatures, then identification of suitable offshore sand deposits should commence now to avoid the growth of unregulated sand replenishment schemes.

Future research needs include an island-wide estimation of vulnerability to storms and sea-level rise (i.e., a modified CVI) to provide the technical background for decision making for coastal development proposals. This should include island-wide re-levelling to ascertain the position of local sea-level at various places around the island. Continuing research is required on perfecting setback guidelines for Integrated Coastal Zone Management; identification of offshore carbonate sand deposits for beach nourishment; expansion of the programme of co-operative for fisher-folks; and satellite-based monitoring of changes in the health of the island's coastal ecosystems.

Tourism

Tourism has been a blue ribbon industry in Jamaica over the past three decades. It provides approximately $1.934 billion US dollars annually to the foreign exchange earnings of the nation and is surpassed only by private remittance inflows as a foreign exchange earner. Between 2002-07, when average GDP growth was 1.6 percent, the tourism sector grew 4.2 percent.

The local tourism product is dominated mainly by resort (sun, sea and fun) tourism and is location specific. The north coast areas (i.e., Montego Bay, Ocho Rios, and Negril) are the dominant areas for both stopover and cruise ship visitors. This is due to the coastal resources (white sand beaches, all inclusive hotels and sea ports and attractions) and infrastructural investments which have gone into these areas.

Two socio-economic scenarios were modelled; one without climate change variables (control scenario) and another with assumptions about a changed climate change. An independent model was also developed to examine visitor arrivals over time.

For the control scenario, visitor arrivals are expected to increase to 3.1 million by 2050. For the scenario with a changing climate, the number of visitors falls to 2.7 million by 2050, resulting in declines in earnings.

Proposed Elements of a Tourism Adaptation Strategy for Jamaica

1. Raise stakeholder awareness of the workings of both tourism and environment;
2. Stakeholder identification of detailed programme and projects;
3. Set up a comprehensive performance framework with targets;
4. Provide more varied visitor attractions to a) put less pressure on existing natural resources and b) stimulate more visitors;
5. Reflect social and environmental costs in the price of tourism products;
6. Improve environmental lobbying;
7. Implement infrastructural changes to protect the environment, e.g., groynes and levees, reforestation, and coastal zone management;
8. Implement education and sensitisation programmes;
9. Intensify community tourism activities; and
10. Increase urban tourism.

Other information considered relevant to implementation of the Convention

Climate change research and systematic observation systems in Jamaica

In 2005, an initial assessment of Jamaica's systematic observation systems was conducted in conjunction with the national Meteorological Service. This assessment comprised of interviews with key personnel, as well as visits to a number of locations where systematic observation systems are located.

The assessment focused on the needs and the requirements of the Meteorological Services, with a view to making recommendations for the improvement of the observation systems in Jamaica. More specifically, the following elements were planned:

(i) A detailed assessment of the coastal, marine, and hydro meteorological systematic observation systems in Jamaica, describing: the types and locations of the equipment; the agencies responsible for the maintenance of the equipment; the scope of climate related data stored, including climate variables observed; the years for which data is available and frequency of data collection.

(ii) An assessment of the current coastal, marine, and hydro meteorological systematic observations systems in Jamaica.

(iii) An identification of the technological and capacity building requirements for the upgrade and improvements of the current systematic observation systems.

It was recommended that 13 automatic weather stations be added to the existing system. Along with some other required upgrades, the total cost of improvements would be US$ 615,853.

Technology Needs Assessment

The technology needs assessment process consisted of a series of expert workshops with key sectoral experts present to discuss issues relating to technology in Jamaica. The first workshop focused on mitigation and energy issues, while the second workshop looked at adaptation issues as they relate to the coastal zone and water sectors in Jamaica. Both workshops used the initial national communication of Jamaica as the document of reference.

A number of issues were considered with regards to criteria for the transfer and development of technologies for mitigation for Jamaica. These included the overall integration with the current energy policy, and the linkage to development goals. In order for a technology to be suitable for Jamaica, it was agreed there a number of key criteria which have to be met. These are:

(i) affordability and low cost,
(ii) environmental and economic impact,
(iii) social acceptability, and
(iv) job creation potential.

The identification of these key criteria was done utilizing expert judgment and stakeholder analysis. It was noted that any technology which is to be transferred to Jamaica should aid in reducing the amount of foreign exchange which is utilized to purchase energy, in addition the technology should be durable, be commercially proven and aid in the development of Jamaica. Further, the proposed technology should be in line with future projected energy scenarios. One possible scenario sees the expansion of capacity from the current 780 MW to 1250 MW by 2015. A demand-side management programme to improve energy efficiency is also underway.

A number of mitigation technology options were identified:

- Natural gas technology for electricity production, especially for the bauxite alumina industries;
- Methane extraction from waste landfills for electricity production;
- Alternative fuels and vehicles, particularly CNG and diesel
- Renewable energy technologies including wind, small-scale hydro, cogeneration and biomass, solar, and Ocean Thermal Energy Conversion

Adaptation technologies were considered for the coastal zone and water resources sectors. A number of issues were considered when criteria for the transfer and development of technologies for adaptation were considered. Stakeholder consultations and expert judgment were used to determine the criteria. It was noted that technologies for adaptation should be: cost effective, proven, flexible, aid in vulnerability reduction, and easy to use. Technologies for adaptation should also look at technologies in the broadest sense.

For improving coastal zone management, the following technologies were identified:

- Beach protection measures such as groynes and revetments;
- Reinstatement of the tidal gauge network (for obtaining data to feed into the geographic information system and aid in planning and project designs, thus ensuring vulnerability reduction occurs;
- Beach profiling (to aid improved data collection); and
- Regeneration of mangroves.

In the water sector, the following needs were noted:

- Improvement and rationalization of the hydrometric network;
- Additional river gauges and more automatic weather stations to aid in data collection and planning to reduce vulnerability;
- Additional flood warning systems; and
- Additional software such as waterware, riverware, and mikebasin to aid in improvement of water management.

The main barrier to the transfer of technology to Jamaica is the high initial capital cost of technologies. There is a need for flexible financial measures in order for new technologies to be adopted. Attitudes, perceptions, and lack of information were also highlighted as a key barrier. In particular, lack of understanding about specific technologies and lack of political will prevent the transfer and adoption of potential technologies. Lack of data is a constraint, particularly with regards to vulnerability issues which prevents adoption and applications of technologies for adaptation. The lack of a central decision making entity to handle issues with regards to technology was also noted as a barrier.

Public Awareness Raising

A number of baseline studies were conducted to obtain a better understanding of the level of education and understanding about climate change in Jamaica. A number of activities were undertaken, including:

(i) *An in house focal point workshop on the Jamaica Phase Two "Top Up" activities*. The purpose of the workshop was to sensitize the relevant persons within the Meteorological Service to the project and the possible outputs.

(ii) *A project launch workshop*. The objectives of this workshop were to: 1) aid in reconvening the National Implementation Coordinating Unit for climate change in Jamaica and 2) launch phase two by informing participants about climate change, regional concerns, climate change scenarios, and alternative energy options for Jamaica.

(iii) *A Climate Change Symposium*. Participants were sensitised to international issues related to climate change, particularly the 10th Conference of Parties of the UNFCCC and the effect that climate change could have on energy, water resources, coastal resources and biodiversity.

(iv) A climate change public education and awareness survey.

Overall, the activities aided in facilitating national networks on climate change and promoting the integration of climate change concerns into the national development planning dialogue.

Table of Content

FIGURES AND TABLES

EXECUTIVE SUMMARY

NATIONAL COMMUNICATION

TABLES

ACKNOWLEDGEMENTS

The Meteorological Service is Jamaica's national focal point to the United Nations Framework Convention on Climate Change (UNFCCC) and was responsible for the preparation and submission of this Second National Communication. The process was undertaken by the Environment and Disaster Management Unit of the Ministry of Local Government. A full time project manager was hired for two years and based in the UNDP Country Office who utilized the skills of international and local consultants and several national experts to prepare this National Communication. The persons listed below are being acknowledged for their sterling contribution to the completion of this document.

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LIST OF ACRONYMS

AAJ	Airports Authority of Jamaica
BEFI	Biomass expansion factor
BHC	Bustamante Hospital for Children
BOD5	Biochemical Oxygen Demand
CAA	Civil Aviation Authority
CAFE	Corporate Average Fuel Economy
CARICOM	Caribbean Community
CCCCC	Caribbean Community Climate Change Centre
CCCL	Caribbean Cement Company Limited
CDERA	Caribbean Disaster Emergency Response Agency
CGE	Consultative Group of Experts on non-Annex I National Communications
CH_4	Methane
CO	Carbon monoxide
COD	Chemical oxygen demand
COP	(UNFCCC) Conference of the Parties
CORINAIR	CORe INventory of AIR emissions
CVI	Coastal Vulnerability Index
DOC	Degradable Organic Carbon
EDMS	Emissions & Dispersion Modelling System
EFJ	Environmental Foundation of Jamaica
EMEP	Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe
ESSJ	Economic and Social Survey of Jamaica
EU	European Union
FAA	Federal Aviation Administration of the United States of America
FAOSTAT	Food and Agriculture Organisation website
FF	Forest Land Remaining Forest Land
FOEB	Fuel oil equivalent barrels
FRA	Forest Resource Assessment
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHGs	Greenhouse gases
Gg	Gigagram
GVWR	Gross vehicle weight rating
GWPs	Global warming potentials
HC	Hydrocarbon
HDV2B	Class 2b Heavy-Duty Vehicles (8501-10,000 lbs. GVWR)
HDV3	Class 3 Heavy-Duty Vehicles (10,001-14,000 lbs. GVWR)
HDV4	Class 4 Heavy-Duty Vehicles (14,001-16,000 lbs. GVWR)
HDV5	Class 5 Heavy-Duty Vehicles (16,001-19,500 lbs. GVWR)
HDV6	Class 6 Heavy-Duty Vehicles (19,501-26,000 lbs. GVWR)
HDV7	Class 7 Heavy-Duty Vehicles (26,001-33,000 lbs. GVWR)
HDV8A	Class 8a Heavy-Duty Vehicles (33,001-60,000 lbs. GVWR)
HDV8B	Class 8b Heavy-Duty Vehicles (>60,000 lbs. GVWR)
HFCs	Hydrofluorocarbons
HWM	High Water Mark
ICAO	International Civil Aviation Organization

ICZM	Integrated Coastal Zone Management
INC	Initial National Communication
IPCC	Inter-governmental Panel on Climate Change
ISIC	International Standard Industrial Classification of All Economic Activities
JCF	Jamaica Constabulary Force
JEP	Jamaica Energy Partners
JPPC	Jamaica Private Power Company
JPS	Jamaica Public Service Company
JSLC	Jamaica Survey of Living Conditions
JTB	Jamaica Tourist Board
JUTC	Jamaica Urban Transit Company
KMA	Kingston Metropolitan Area
LDT1	Light-Duty Trucks 1 (0-6,000 lbs. GVWR, 0-3750 lbs. LVW)
LDT2	Light-Duty Trucks 2 (0-6,000 lbs. GVWR, 3751-5750 lbs. LVW)
LDT3	Light-Duty Trucks 3 (6,001-8,500 lbs. GVWR, 0-5750 lbs. ALVW)
LDT4	Light-Duty Trucks 4 (6,001-8,500 lbs. GVWR, 5751 lbs. and greater ALVW)
LDV	Light-Duty Vehicles (Passenger Cars)
LF	Land Converted to Forest Land
LPG	Liquefied petroleum gas
LTOs	Landings and take-offs
MACC	Mainstreaming Adaptation to Climate Change in National Development Planning
MAI	Mean annual increment
MCF	Methane Correction Factor
MDIs	Metered Dose Inhalers
MEMT	Ministry of Energy, Mining and Telecommunication
MGU	Marine Geology Unit, University of the West Indies
MHWM	Mean High Water Mark
MMS	Manure management system
MSL	Mean Sea Level
MSW	Municipal Solid Waste
MSWB	Municipal solid waste burned
MSWH	Mean Significant Wave Height
N_2O	Nitrous oxide
NCSP	National Communications Support Programme
NDBC	National Data Buoy Centre
NEPA	National Environment and Planning Agency
NFPB	National Family Planning Board
NMIA	Norman Manley International Airport
NMVOC	Non-methane volatile organic compounds
NOAA	National Oceanic and Atmospheric Administration
NOx	Nitrogen oxides
NRCA	Natural Resources Conservation Authority
NSWMA	National Solid Waste Management Authority
NWC	National Water Commission
ODPEM	Office of Disaster Preparedness and Emergency Management
ODS	Ozone depleting substances
ODU	Oxidised during use
PDI	Power Dissipation Index

PFCs	Perfluorocarbons
PIOJ	Planning Institute of Jamaica
PSP	Permanent Sample Plots
RAC	Refrigeration and air-conditioning
RADA	Rural Agricultural Development Authority
SBSTA	(UNFCCC) Subsidiary Body for Scientific and Technological Advice
SIA	Sangster International Airport
SIDS	Small Island Development States
SMB	St. Margaret's Bay
SNAP97	Selected Nomenclature for Air Pollution
SNC	Second National Communication
SO_2	Sulphur dioxide
SRC	Scientific Research Council
SST	Sea Surface Temperatures
STATIN	Statistical Institute of Jamaica
SWIL	Smith Warner International Ltd.
TOR	Terms of Reference
UDC	Urban Development Corporation
UHWI	University Hospital of the West Indies
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNITAR	United Nations Institute for Training and Research
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
V&A	Vulnerability & Adaptation
VOB/ha	Volume over bark per hectare
WRA	Water Resources Authority
WTO	World Tourism Organization

BACKGROUND

(i) The UNFCCC Context

The United Nations Framework Convention on Climate Change (UNFCCC) entered into force on 21 March 1994 and sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change. All Parties must report on the steps they are taking or envisage undertaking to implement the UNFCCC (Articles 4.1 and 12.1) by: "reporting to the Conference of the Parties (COP) on emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol (greenhouse gas inventories); national or, where appropriate, regional programmes containing measures to mitigate, and to facilitate adequate adaptation to climate change (general description of steps taken or envisaged by the Party to implement the Convention); and any other information that the Party considers relevant to the achievement of the objective of the Convention." (UNFCCC, 2003) This national report is referred to as a National Communication.

Jamaica ratified the Convention on January 6, 1995, by an act of Parliament and the instrument of ratification was deposited at the United Nations in April 1995. The Meteorological Service is the UNFCCC national focal point and responsible for submission of Jamaica's national communications. Jamaica submitted its Initial National Communication to the UNFCCC on 21 November 2000.

(ii) Financial and Technical Assistance for Preparing National Communications

The Global Environment Facility

The Global Environment Facility (GEF) provides financial assistance to non-Annex I Parties to prepare their national communications under guidance from the COP. This financing is made available under projects called "enabling activities", which are implemented through the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and World Bank.

Key differences between funding for Initial and Second National Communications

Countries that chose expedited funding for their Initial National Communications received up to $350,000 from the GEF. For Second National Communications, this sum rose to $420,000, which includes $15,000 for an initial stocktaking exercise, stakeholder consultations and the preparation of the project proposal. This preliminary exercise is a critical step so that Second National Communications build on the results, experiences and lessons learned of Initial National Communications, thus ensuring improvements are carried out in a more cost-effective manner and are not duplicative.

The Secretariat of the United Nations Framework Convention on Climate Change

One function of the UNFCCC Secretariat is to facilitate the provision of financial and technical assistance to non-Annex I Parties as they prepare national communications. One mechanism for providing assistance is through the Consultative Group of Experts on non-Annex I National Communications (CGE). In the region, the CGE conducted hands-on training workshops on greenhouse gas (GHG) inventories and vulnerability and adaptation (V&A) assessments, as well as a global one on mitigation analysis in the context of the preparation of national communications. The thematic training materials developed and used at these training workshops have been used by Jamaican national experts during the preparation of national communications.

The UNDP/UNEP National Communications Support Programme

The National Communications Support Programme (NCSP) is a UNDP/UNEP project, funded by the GEF, which provides technical and policy support to non-Annex I Parties for the preparation of national communications. The NCSP is based at the UNDP office in New York. The governments of Switzerland and the USA have co-financed NCSP activities.

During its second phase (2005-2010), the NCSP is sustaining capacity-building efforts through technical and policy support, knowledge management, and communications and outreach. The NCSP offers an integrated package of technical and policy support to enhance capacity in non-Annex I countries and to better meet the needs of countries, such as targeted, in-depth and issue-specific workshops and technical backstopping. The NCSP also promotes the quality and comprehensiveness of national communications and the timeliness of their submission, and assists non-Annex I Parties to better incorporate climate change into national development policies.

(iii) Other Resources

<u>Mainstreaming Adaptation to Climate Change into National Development Planning</u>: In the Caribbean, the World Bank implemented a four-year (2004-2007), GEF-funded project, *Mainstreaming Adaptation to Climate Change into National Development Planning (MACC)*, which aimed to integrate climate change and variability into the agendas of the tourism, agriculture, fisheries and infrastructure sectors. This regional project included the 14 member states of the Caribbean Community (CARICOM) namely Antigua & Barbuda, The Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, St. Kitts & Nevis, St. Lucia, St. Vincent & the Grenadines, Trinidad & Tobago, and Suriname. The project was implemented through the Caribbean Community Climate Change Centre (CCCCC), the regional centre for Caribbean climate change activities located in Belize.

<u>Caribbean Community Climate Change Centre (CCCCC)</u>: The stated mission of the CCCCC is "through its role as a Centre of Excellence, the Centre will support the people of the Caribbean as they address the impact of climate variability and change on all aspects of economic development through the provision of timely forecasts and analyses of potentially hazardous impacts of both natural and man-induced climatic changes on the environment, and the development of special programmes with create opportunities for sustainable development".

The Centre coordinates the Caribbean region's response to climate change. Officially opened in August 2005, the Centre is the key node for information on climate change issues and on the region's response to managing and adapting to climate change in the Caribbean. It is the official repository and clearing house for regional climate change data, providing climate change-related policy advice and guidelines to CARICOM Member States through the CARICOM Secretariat. In this role, the Centre is recognised by the UNFCCC, UNEP, UNDP, and other international agencies as the focal point for climate change issues in the Caribbean. It has also been recognised by the United Nations Institute for Training and Research (UNITAR) as a Centre of Excellence.

UNDP Jamaica: The UNDP Country Office in Jamaica provided $USD 10,000 for the communications strategy for the report, Voices for Climate Change. It provided a further $USD 50,000 for a communications and advocacy component, which included high-level, round table sessions.

CHAPTER 1: NATIONAL CIRCUMSTANCES

1.1 History and Politics

Jamaica is an island nation in the Caribbean Sea and a part of the group of islands that are known as the Greater Antilles[1]. Jamaica is located approximately 145 kilometres (90 miles) south of the island of Cuba and was discovered by Christopher Columbus in 1494. At that time, it was inhabited by Arawakan-speaking Taino Indians, who had named it Xaymaca, which means the "Land of Wood and Water" or the "Land of Springs". Upon possession by the Spanish, it became known as Santiago and then Jamaica after it was possessed by the British in 1655. Jamaica achieved full independence in 1962.

Jamaica has a constitutional monarchy, represented by a Governor General who is the local representative of Queen Elizabeth II (the de facto head of state with the title, Queen of Jamaica). The Governor General is nominated by the Prime Minister and the cabinet nominated by the monarch. The government is bicameral, with a House of Representatives and a Senate. Members of the lower house (MPs) are directly elected and it is from these MPs that the Prime Minister is chosen. Members of the Senate are chosen by the Prime Minister and the Leader of Opposition.

Administratively, the nation is divided into 14 parishes within which exist 60 parliamentary constituency seats and also numerous parish councils. The country has traditionally had a two-party system which has been dominated by the People's National Party and the Jamaica Labour Party. The Jamaican system of government exhibits a relatively stable democracy. Since independence, the country has never had a coup d'état and elections, especially in recent times, have been judged free and fair.

Jamaica is an active member in CARICOM (Caribbean Community), a regional free-trade association based in Guyana whose main purposes are to promote economic integration and cooperation among its members and to coordinate foreign policy. The treaty establishing CARICOM was signed on 4 July, 1973; a revised treaty was signed in 2001.

Jamaica is also a member of the Alliance of Small Island States, AOSIS a coalition of small islands and low-lying coastal countries that share similar development challenges and concerns about the environment, especially their vulnerability to the adverse effects of global climate change[2].

1.2 Population and Demographics

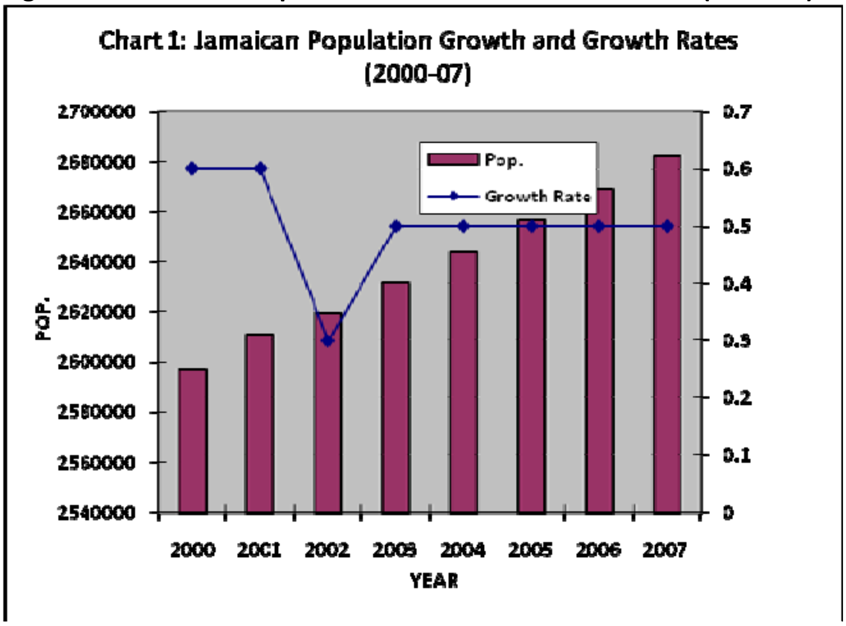
1.2.1 Population & Growth Rate

Jamaica is the third most populous Anglophone country in the Americas after the USA and Canada. Official statistics from the Planning Institute of Jamaica (PIOJ) and Statistical Institute of Jamaica (STATIN) show that, as at 2007, Jamaica had a resident population of 2,682,100 (representing end of year population). Demographically, Jamaica's population has consistently comprised four major ethnic groups: black, 90 per cent; East Indian, 1.5 per cent; whites, 0.4 per cent; and multi-racial, 7.4 per cent.

[1] The Greater Antilles are; Jamaica, Cuba, Puerto Rico and Hispaniola.
[2] http://www.sidsnet.org/aosis/about.html

With regard to overall human and social development the country is classified as at Stage III in the Demographic Transition Model.[3] Although the population has been growing steadily at an average annual rate of about 0.5 to 0.7 per cent since 2000, it has not reached beyond 3 million (Figure 1.1).

Figure 1.1: Jamaican Population Growth and Growth Rates (2000-07)



(Sources: PIOJ/STATIN)

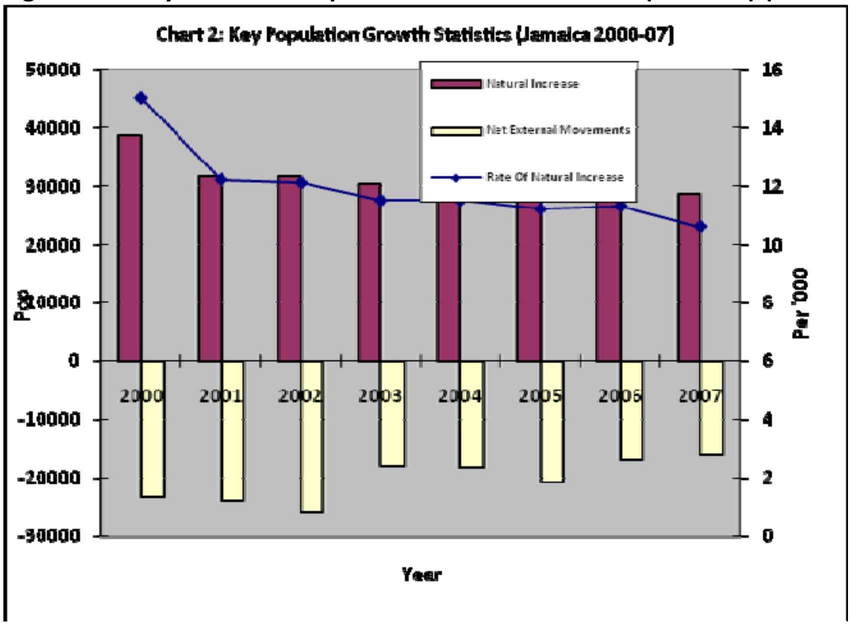
There are two main reasons that the population has remained relatively stable over the past decade:

1. The rate of natural increase (which represents the difference between crude birth rate and crude death rate) has shown significant declines over the period 2000-07, falling from 15 per thousand in 2000 to 10.6 per thousand in 2007; and
2. The impact of a steady stream of external migration over the decades (Figure 1.2).

[3] This is a model used to explain the gradual change in demographic structure of a country as it moves from pre-industrial to an industrialized society. Stage Three (III) is typified by:

- Increasing urbanization
- Introduction of compulsory education acts
- Increasing female literacy and employment
- Improvements in contraceptive technology and methods

Figure 1.2: Key Jamaican Population Growth Statistics (2000-07) (Sources: PIOJ/STATIN)



There is nothing that suggests an upward trend in crude birth rates for the future. Rather, as shown in Table 1.1, there have been relative declines of women in younger age groups cohorts who are entering the reproductive phase (i.e., 15-19, 20-24, and 25-29 years) over 2000-07. There has also been a serious drive on Family Planning and Reproductive Health over the past three decades. For instance, the 2006-10 Strategic Planning Framework for the National Family Planning Board (NFPB) was designed to achieve: [a] expanded access to existing but underused family planning and reproductive health (RH) options for women, [b] improved access to RH information for adolescents/youth, [c] expanded access to RH information services for men, and [d] promote safe sexual behaviour, attitudes and practices to reduce the prevalence of STDs and HIV/AIDS. At present, the NFPB targets more than 0.5 million of the population[4] to promote family planning methods, of which 250,000 attend clinics.

Table 7.1: Distribution of Women in the Reproductive Ages (15-49) years

AGE GROUP	YEAR				
	2003	2004	2005	2006	2007
15-19	17.7	17.4	17.1	16.9	16.6
20-24	15.6	15.4	15.1	14.9	14.6
25-29	15.6	15.5	15.5	15.4	15.3
30-34	15.4	15.4	15.5	15.6	15.7
35-39	14.9	15.2	15.4	15.7	15.9
40-44	12.1	12.3	12.6	12.7	12.9
45-49	8.7	8.8	8.8	8.8	9.0

Source: PIOJ – ESSJ 2007

With respect to migration, official statistics on net external movement show that annually approximately 20,000 more Jamaicans migrate from the island than foreigners come to settle. The dominant stream of outward migration from Jamaica is to the USA. Official statistics from the

[4] 68 per cent of women in the reproductive age group of 15-49 years

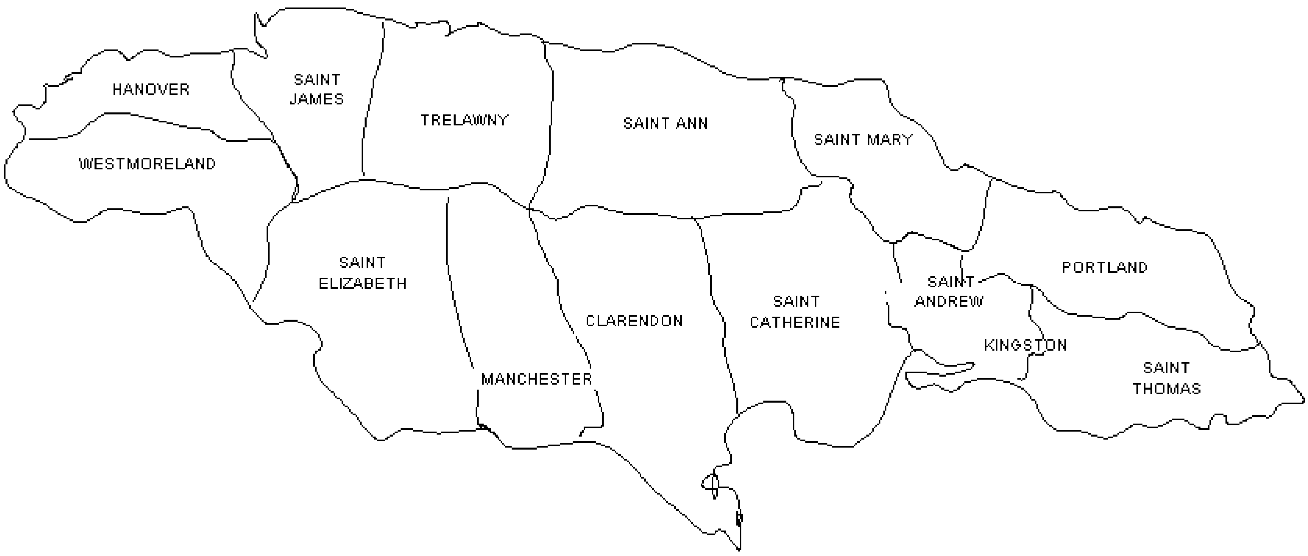
Immigration and Naturalization Service (USA) shows a strong and negative correlation[5] (-0.9989) between the age cohort of migrants and also the number of migrants who migrate from each age cohort. In short, the younger the age cohort is the larger the number of migrants. This pattern for both sexes in each age cohort has existed as far back as 1996.

The Jamaican population is showing marginal evidence of ageing. The over-75 age group has risen from 3.1 per cent of the total end of year population in 2000 to 3.6 per cent in 2004 and 3.8 per cent in 2007. In contrast, the 0-4 age cohort fell from 11.3 per cent in 2000 to 9.2 per cent in 2004 and 8.4 percent in 2007. As noted earlier, these trends can be attributed to the declining birth rate and the impact of migration (which is usually younger age groups). Increased life expectancy is another key variable.

For the Jamaican population, life expectancy has averaged 72.1 years since 2000 but is trending up each year. The current world average is 78 years. Ceteris paribus, projections show that at the current rates, life expectancy will reach current world average in 2097. Improved health care is a key factor. Although a developing country, Jamaica has made considerable strides over the past three decades with regard to health care, especially so for women. A higher percentage of people from all socio-economic groups are reporting illnesses and injuries (10.3 and 14.1 per cent of males and females respectively in 2006 versus 9.7 and 11.8 per cent in 1996). Health care expenditure at both private and public facilities has also increased between 1996-06. All statistics both real and nominal show an increase in private investment in visits to facilities and drug purchases over the period. Real mean health care expenditure on visits to private health facilities has increased by 9.8 per cent between 1996-06 and by 170 per cent for public health facilities over the same period. With regard to drug purchases, there have been real increases in average expenditure from both private and public health care facilities between 1996-06. Private real increases in average drug purchases increased 211 per cent. All these variables can be seen as assisting an increase in life expectancy.

1.2.2 Population Distribution

Map of Jamaica (Parishes)



Source: http://prestwidge.com/images/jatoday.gif

[5] This variable represents two major comparison variables spearman rank correlation co-efficient and also the linear regression correlation coefficient.

Since 2000, the largest population concentrations are found in the parishes of Kingston and St Andrew (24.7 per cent) and St Catherine (18.5 per cent), with the lowest concentration in Hanover (2.6 per cent). Further details are shown in Table 1.2 below.

Table 1.8: Comparison of End of Year Populations in Jamaica (2000 & 2007)

PARISH	2000		2007	
	END OF YEAR POPULATION	% DISTRIBUTION	END OF YEAR POPULATION	% DISTRIBUTION
Kingston & St Andrew	646, 100	26.9	663,600	24.7
St Thomas	85,300	3.6	93,900	3.5
Portland	76,500	3.2	81,900	3.1
St Mary	109,200	4.6	113,900	4.2
St Ann	150,600	6.3	172,800	6.4
Trelawny	71,400	3.0	75,300	2.8
St James	156,200	6.5	183,700	6.9
Hanover	66,400	2.8	69,600	2.6
Westmoreland	128,900	5.4	144,400	5.4
St Elizabeth	146,100	6.1	150,600	5.6
Manchester	161,600	6.7	190,200	7.1
Clarendon	215,980	9.0	245,600	9.2
St Catherine	384,500	16	496,000	18.5

Source ESSJ – PIOJ/STATIN

Approximately 52 per cent of the population lived in urban areas in 2001 – an increase of almost 12 per cent since 1970. The rate of urbanization varies by parish. As shown in Table 1.3, the fastest urbanizing parish is St. Catherine, which has doubled its urban size since the 1970s, increasing at a rate of 1.3 per cent per year. St James, Manchester, St Elizabeth and Westmoreland also have increasing urban populations.

Table 1.9: Urban-Rural Distribution by Parish (1970-2001)

PARISH	1970	1982	1991	2001
Jamaica	40.6	47.8	49.6	52.0
Kingston	100	100	100	100
St. Andrew	88.0	87.0	86.3	86.9
St. Thomas	21.7	25.8	25.9	28.2
Portland	20.5	21.7	20.8	23.5
St. Mary	17.8	21.5	20.8	20.8
St. Ann	19.2	18.9	24.5	26.8
Trelawny	12.7	18.2	18.4	19.6
St. James	43.5	51.7	55.2	55.5
Hanover	6.2	9.0	8.3	9.3
Westmoreland	14.7	15.4	19.3	25.7
St. Elizabeth	5.2	9.0	10.1	14.4
Manchester	21.2	33.8	33.7	33.5
Clarendon	22.5	27.7	30.0	30.3
St. Catherine	34.8	63.0	70.1	73.8

Source: Population Census 2001 – STATIN

1.2.3 Education and Literacy

The literacy rate in Jamaica in 2007 was estimated to be 86 per cent, while according to the CIA World Fact Book, the world literacy rate currently (2007) sits at 82 per cent. The Jamaican society has traditionally put a premium on education. More than half of the social budget (both capital and recurrent expenditure) is spent on education. Of the current[6] J$380 billion dollar recurrent and capital budget, 12.4 per cent is dedicated to Education and Cultural Development (versus 8.2 per cent for security services, 5.2 per cent for health, and 3.4 per cent for economic services). The education system is fully managed and run by the Ministry of Education and Youth.

Enrolment in primary schools (ages 5-10) and secondary schools (ages 10-16) are currently[7] over 80 per cent. Enrolment in tertiary studies has risen from 20 per cent to 34.5 per cent from 2000-2006. Total output of skilled and semi-skilled workers increased from 28,900 individuals to 49,900 from 2002- 2007.

1.2.4 Housing

Most Jamaicans (78 per cent) live in separate/detached housing. Over 70 per cent of households are owner-occupied or rent free and approximately 20 per cent are rented. The typical house in Jamaica is constructed of block and steel material (approximately 70 per cent). Wood (21 per cent) and concrete "nog" (9 per cent) are also used. Investigation of type and quality of amenities shows the following:

- Between 1996-06, approximately 68 per cent of households were supplied with piped water. Public standpipe comprises 6.7 per cent of water supply to households, trucked water approximately 3 per cent, spring or pond 3.9 per cent, rainwater (tank) approximately 15 per cent and wells approximately 3.5 per cent.
- Between 1996-06, 65 per cent of households had access to flush toilets and a further 33 per cent used pit latrines. The number of flush toilets is increasing and pit latrines decreasing.
- Electricity is the main source of lighting currently for 90 per cent of Jamaican households, followed by kerosene lighting (7.1 per cent). Only 2 per cent of households have no lighting.
- 91.6 per cent of households have exclusive access to a kitchen

The Housing Quality Index[8] (HQI) for Jamaica has increased by almost 10 per cent between 1996-06 (Table 1.4). This may be because there is increasing use of more durable materials in construction, and marked increases in exclusive use of utilities and amenities in houses. In short, homes in Jamaica are getting more modern. As a result the housing quality index has increased by almost 10 per cent in 10 years (Table 1.4).

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[6] 2007

[7] 2007

[8] The HQI is an internationally accepted measure which measures the quality of the housing stock. The components of the HQI are: materials of outer walls, exclusive use of water closets, dwellings with indoor pipes/taps, electricity for lighting, exclusive use of kitchen and number of habitable rooms.

Table 1.4: Housing Quality Index for Jamaica

PARTICULARS	1996	1997	1998	1999	2000	2001	2002	2004	2006
Walls of Block and Steel	55.6	59.2	59.6	58.3	62.7	63.3	58.4	64.3	65.1
Exclusive Use of Water	44	45.2	47	47.7	48.8	50.7	50.5	54.9	57.2
Indoor Taps	44.3	46.2	42.3	44.3	46.3	46.6	45	49.3	48.5
Electricity for Lighting	76.9	78.2	80.4	80.8	86.9	86.1	87.1	89	90
Exclusive Use of Kitchens	82.8	81.1	89.3	89.6	91	92.4	90.5	90	93.6
% of Households that meet International Standard for No. of Persons per Habitable Room	47.9	50.6	50.1	53.8	54.6	56	50.8	48.7	50
HQI	58.5	60	61	62.4	65	65.8	63.7	66	67.4

Source: Jamaica Survey of Living Condition

1.2.5 Culture and Sport

Jamaica has a high interest and record of achievement in some of the world's major sports. It is a participating member in the West Indies Cricket Board and cricket team, its national football team has played in the World Cup (1998), and the national bobsled team has competed in the Winter Olympics. Rifle shooting, horseracing, netball and basketball are also popular. It is however in track and field where Jamaica has an iconic standing worldwide, with numerous world record holders and Olympic and World championship medals for both males and females in sprint races. The Jamaican culture also has a strong global presence as evidenced by its musical genres (e.g. ska, rock steady, reggae etc), art, food, dance and literature.

1.3 Geography and Climate

At approximately 2000 square miles, Jamaica is the third largest island in the Caribbean. The island is approximately 230 km long, oriented in an east-west axis and is approximately 80 km at its widest point. Land area is 10,990 sq. Km, of which about 160 sq. km is water and the coastline is approximately 1,022 km. The terrain is characterised by a mountainous region along the island's east west axis and narrow coastal plains. The highest elevation is Blue Mountain Peak which is 2,256 m above sea level. Most major towns and cities are located on the coast, with its chief towns and cities being the capital Kingston, Montego Bay (its second city), Mandeville, Spanish Town Ocho Rios, and Pt Antonio. Only two major parish capitals are located inland.

The local climate is deemed tropical, with coastal areas having hot and humid weather and inland areas having a more temperate climate. Jamaica lies in the hurricane belt of the Atlantic Ocean which historically has been evidenced by strong tropical hurricanes. The more recent ones, Hurricanes Dean (2007) and Ivan (2004), have created huge infrastructural damages and some loss of life.

Jamaica's freshwater resources come from surface sources (rivers and streams) and underground sources (wells and springs) and rainwater harvesting. Groundwater supplies most water demands (approximately 80% of production) and represents 84% of the island's exploitable water. The island's water sources are associated with major rock formations and their interrelationships. The three dominant "hydro-stratigraphic" units are basement aquiclude, limestone aquifer, and alluvium aquifer/aquiclude. The island is divided into ten hydrological basins.

Raw water supplies are directly affected by changes in climatic conditions. Changes in the amount of rainfall as well as its frequency and intensity determine the amount of water that will be available for exploitation. The changes to the amount of total rainfall that Jamaica may receive under the climate change scenarios are uncertain; however, even minor changes in Jamaica's rainfall patterns could have significant impacts on its water resources.

1.4 Economy

Jamaica operates a mixed economic system; where there are prominent state enterprises alongside a viable private sector. The major sectors of the Jamaican economy are bauxite, tourism, agriculture, and manufacturing, with tourism and mining being the leading foreign exchange earners. The economy has become more service driven over time – presently (2007) 34.2 per cent of the economy can be seen as the goods sector and 72.9 per cent as the service sector, while in 1992, 42.6 per cent of the economy was goods and 39.7 per cent in 2000.

1.4.1 Key economic sectors

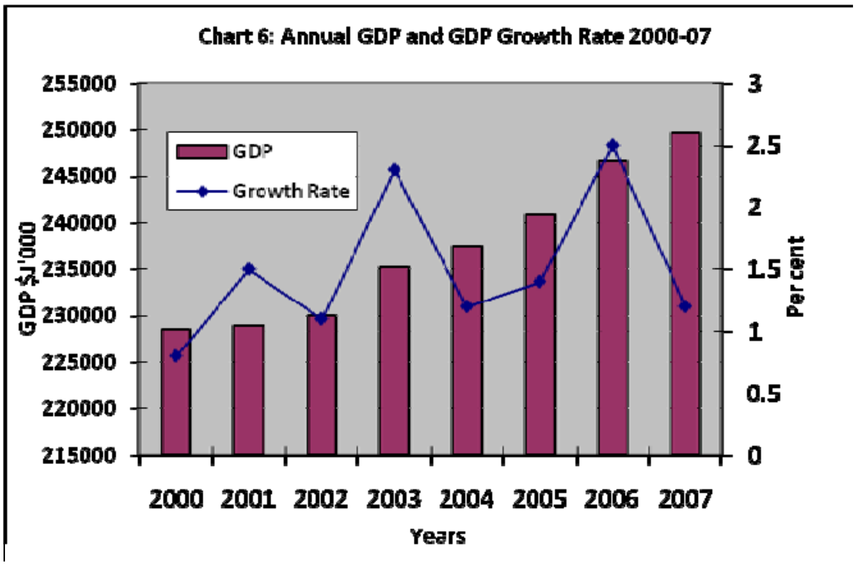
Tourism provides approximately 1.9 billion US dollars annually to the foreign exchange earnings of the nation. It is only surpassed by private remittance inflows as a foreign exchange earner. The local tourism product is dominated mainly by resort ("sun, sea and fun") tourism and is location specific. The north coast areas (i.e., Montego Bay, Ocho Rios, and Negril) are the dominant areas for both stopover and cruise ship visitors.

The agriculture sector has been consistently declining over the past two decades. Its contribution to GDP in 2005 was 5.3 per cent, compared to 6.5 per cent in 2000. The agricultural production index (base year 1996) also shows that the production and value of export crops and domestic crop production have been falling, although the livestock and fishing subsector have shown growth between 1998-07.

1.4.2 GDP Growth Rate and Per Capita GDP

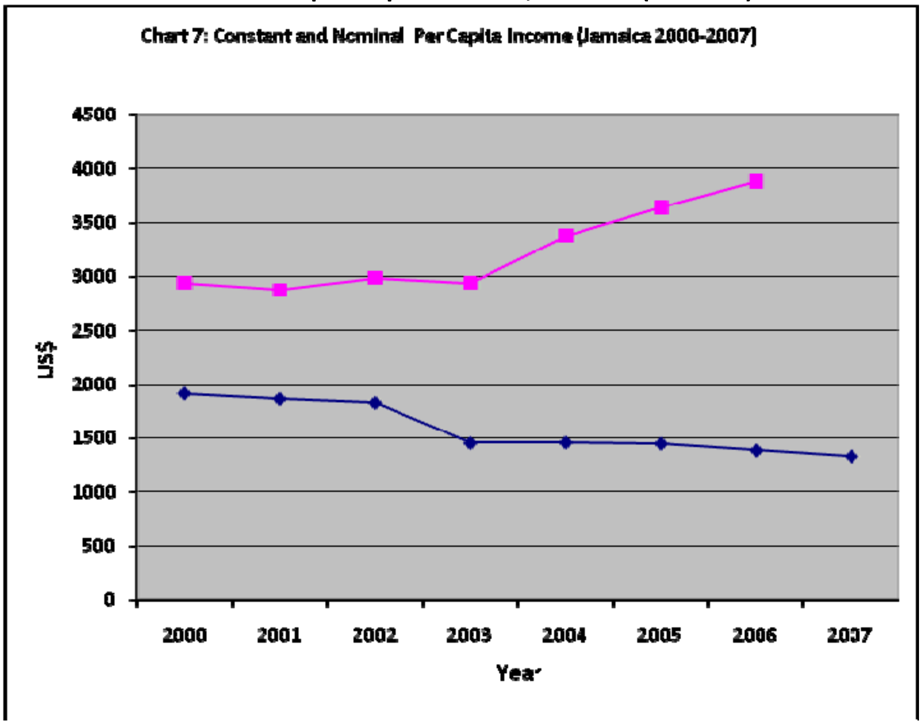
GDP represents the per unit total value of goods and services produced per year by the Jamaican economy. It includes all final goods and services produced by economic resources located in the nation, regardless of ownership and are not resold in any form. The economy had an annual size (in terms of GDP) of approximately J$250 billion in 2007 (Figure 1.3). From 2000-07, the country averaged real growth of 1.5 per cent per annum, ranging from 0.8 per cent in 2000 to 2.5 per cent in 2006 (Figure 1.3).

Figure 1.3: Annual GDP and GDP Growth Rate, 2000-07



Nominal per capita GDP has averaged approximately US$3300.00 from 2000-2007. Constant per capita GDP has been lower, averaging US$1300.00 over the same period (Figure 1.4).

Figure 1.4: Constant and Nominal per Capita Income, Jamaica (2000-07)



1.4.3 International Trade

Being a typical small island developing state (SID), Jamaica can be classified as an open economy. Exports were on average 18 per cent of GDP and imports are 50 per cent. The trade balance currently[9] stands at US$ -3.5 billion and the current account balance at US$ -1.5 billion.

The major trading partner is the USA, which accounted for 33 per cent of the nation's exports, followed by Canada (14 per cent) and the United Kingdom (13.4 per cent). This has implications for demand management of the economy, since an import driven economy (accompanied by commensurately low exports) is a major sign of vulnerability (politically, socially and economically).

Since the adoption of the freely floating exchange rate system, the Jamaican dollar has fallen from J$5: US$1 to J$71: US$1 in 2007. The openness of the economy has also exposed the country to imported inflation which currently, with the recent surge in the price of oil, has affected local price increases. Another critical factor is that imports are major leakages (especially imports of consumer goods which is a major aspect of local imports) and that has also been a factor which has affected the slow rates of growth the economy has undergone over the past decade

Politically this also has implications where with globalization and internationalization being *the* thrust to which all states have to respond. It creates a situation where SIDS such as Jamaica are vulnerable to: [a] free trade agreements by larger economies, e.g. banana and bauxite trade deals, [b] environmental lobbying where, because of their lack of economic power, they are not able to properly table the environmental issues which affect them the most, and, finally [c] trade imbalances that create indebtedness and force countries such as Jamaica with few resources to borrow even further.

1.4.4 National Debt and Its Consequences

Jamaica has a currently[10] existing and rising debt burden of J$990.8 billion. Examination of the annual recurrent and capital expenditure budget shows that debt management is an annual J$205 billion. This is almost 54 cents of every dollar budgeted annually. Debt challenges (and, in some cases, crises) have existed in Jamaica for almost 40 years (albeit, the country has only been politically independent for 48 years). Debt and its consequences are not just a part of the modern culture of the country but a part of an entire generation growing up knowing no other socio-economic scenario. This is a poignant fact when given the charges to be undertaken with the onset of global warming and climate change, which will require an incredible amount of resources to address, and will be especially critical in a country where over one-half of resources earned annually are transferred out to service past economic indiscretions.

1.4.5 Monetary aid

The national economy is a consistent beneficiary of extensive multi-lateral financial and technical assistance from organizations such as the World Bank, the International Monetary Fund, and the Inter-American Development Bank. Strong assistance from these organizations since the 1980s has been

[9] 2008

[10] 2008

instrumental for the implementation of structural reforms, paving the way for a liberal foreign exchange system, cutting of tariffs and trade controls, stabilizing the currency and controlling inflation. The annual amounts of official development assistance for 2001-07 are shown below in Table 1.5.

Table 1.5: Sources of New Official Development Assistance, 2001-07 (US$ Million)

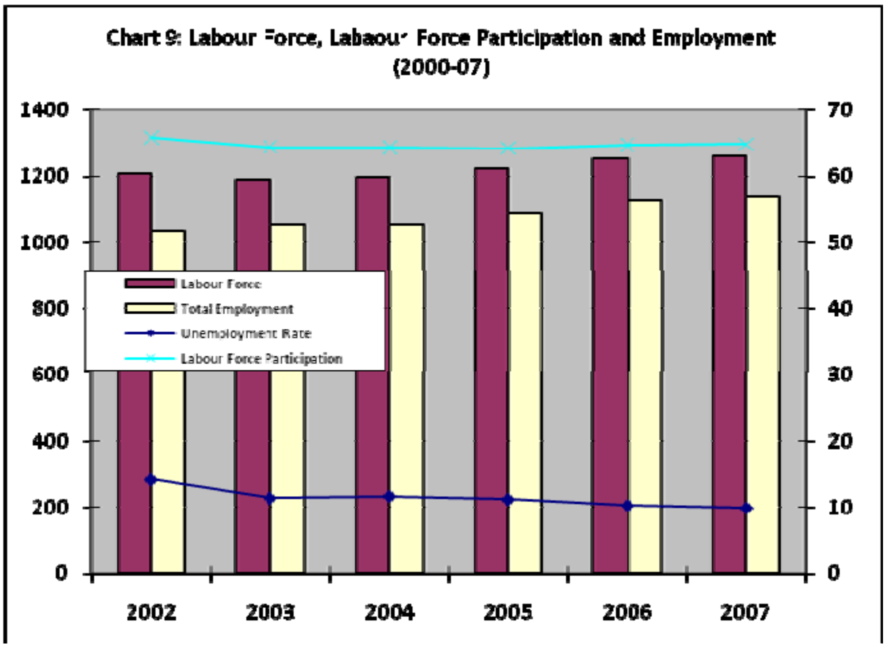
	2001		2002		2003		2004		2005		2006		2007	
AGENCY	Loan	Grant	Loan	Grant	Loan	Grant	Loan	Grant	Loan	Grant	Loan	Grant	Loan	Grant
Bilateral Co-operation	12.9	29.2	-	9.0	-	10.7	-	36.1	105.0	84.0	532.9	19.7	12.9	9.6
Multilateral Financial Institutions	238.8	32.8	221.8	9.5	28.7	71.7	92.4	38.6	54.1	8.9	30.5	8.2	77.3	49.0
Multilateral Technical Cooperation	-	4.4	-	5.3	-	6.6	-	29.0	-	5.4	-	3.3	-	8.6
TOTAL	251.7	66.4	221.8	23.8	28.7	89.0	92.4	103.7	159.1	98.3	563.4	31.2	90.2	67.2

Source: PIOJ and IDPs 2007

1.4.6 Unemployment

The national unemployment rate averaged 11.4 per cent (2000-2008) and has been showing a marginal downward trend since 2000 (Figure 1.5). The labour force has a size of approximately 1.2 million individuals; of this, more than 55 per cent are males. The overall labour force participation rate has undergone marginal declines since 2000 and stood at 64.8 per cent in 2007. There are significant differences between male and female unemployment in Jamaica. Male levels have ranged from 10 per cent (2002) to 6.2 per cent in 2007, while female unemployment averages 17 per cent and has ranged from 20 per cent to 14.5 per cent.

Figure 1.5: Labour Force, Labour Force Participation and Employment (2000-07) (PIOJ)



1.4.7 Poverty and Income Distribution

The incidence of poverty in Jamaica has undergone significant decline, falling from 18.7 per cent in 2000 to 14.3 per cent in 2006. There is a clear relationship between rural locations and higher incidences of poverty. Over 60 per cent of the poor are in rural areas, compared with an average 14-20 per cent in the Kingston Metropolitan Area. There are also marked differences between the mean per capita consumption of rural area towns and the Kingston Metropolitan Area.

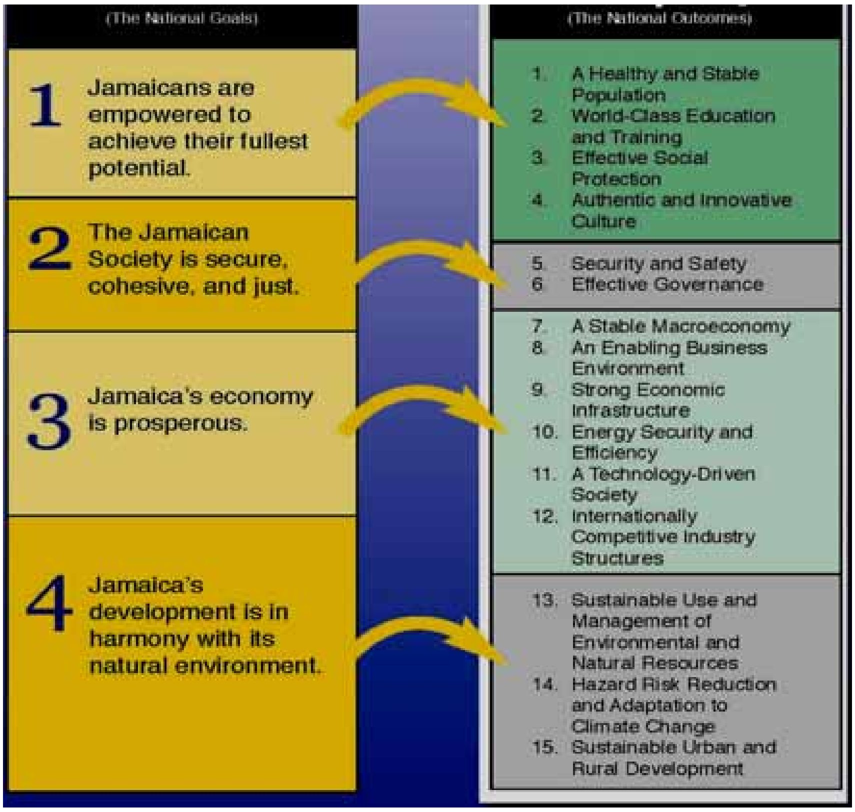
1.5 Vision 2030 Jamaica: National Development Plan

Jamaica's overarching strategic direction that will guide the country's development to 2030 is articulated in Vision 2030 Jamaica: National Development Plan, and is based on the comprehensive vision "Jamaica, the place of choice to live, work, raise families, and do business". The plan is expected to result in Jamaica achieving developed country status by 2030. There are four national goals, 15 national outcomes, and over 50 national strategies to achieve them (Figure 1.6).

The national strategies will be implemented through sector level programmes, plans and activities for each of the social, governance, economic and environmental sectors of the country. Vision 2030 Jamaica will be supported by seven three-year, medium-term socioeconomic policy framework (MTF) documents. The MTF 2009-2012 is the first such document, which focuses on six priority outcomes:

- Security and Safety
- A Stable Macro economy
- Strong Economic Infrastructure
- Energy Security and Efficiency
- World Class Education and Training
- Effective Governance

- **Figure 1.6: The National Goals and Outcomes of Vision 2030 Jamaica: National Development Plan**



CHAPTER 2: THE NATIONAL GREENHOUSE GAS INVENTORY

2.1 Introduction

2.1.1 Background

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.

Jamaica, which is a non-Annex 1 Party to the Convention, included a GHG inventory with its Initial National Communication that was submitted on November 21, 2000. The inventory was prepared for the reference year 1994 in compliance with Articles 4 and 12 of the UNFCCC and in accordance with the Intergovernmental Panel on Climate Change (IPCC) Revised 1996 Guidelines.

For its Second National Communication, Jamaica decided to use the 2006 IPCC Guidelines in preparation of GHG inventories for the years 2000-05. The use of the 2006 Revised IPCC Guidelines fulfils the objective of the Conference of the Parties for the use of comparable methodologies. The inventory was prepared using the following documents:

- *2006 IPCC Guidelines for National Greenhouse Gas Inventories*
- *Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC, 2003)*
- *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000)*

2.1.2 Scope

The gases included in the GHG inventory are the direct GHGs, namely: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6), and the indirect GHGs (which contribute to Tropospheric ozone formation): non-methane volatile organic compounds (NMVOCs), carbon monoxide (CO), nitrogen oxides (NOx), and sulphur dioxide (SO_2).

Inventories were compiled for the years 2000 to 2005 for the following four sectors:

- Energy;
- Industrial Processes and Product Use;
- Agriculture, Forestry and Other Land Use (AFOLU); and
- Waste.

Within each sector, the methodologies used and data sources (activity and emission factor data) are indicated together with the presentation and discussion of emission estimates. Gaps, data constraints, methodological problems and uncertainties in compiling the GHG emission estimates are identified within each sector. The lack of a complete archive of data for the 1994 inventory precluded recalculation of the 1994 inventory using the *2006 IPCC Guidelines* or the investigation of apparent anomalies in estimates of the CO_2 sink in the forestry sector and CH_4 emissions from soils in the 1994 estimates.

2.2 Overview and Summary of Jamaica's Greenhouse Gas Inventory

2.2.1 Comparison between the reference years of 1994 and 2000

Overall national and sectoral emissions for 2000 are given in Table 2.1 and are illustrated in Figure 2.1.

Figure 2.1: Summary of National GHG Emissions in Jamaica (2000)

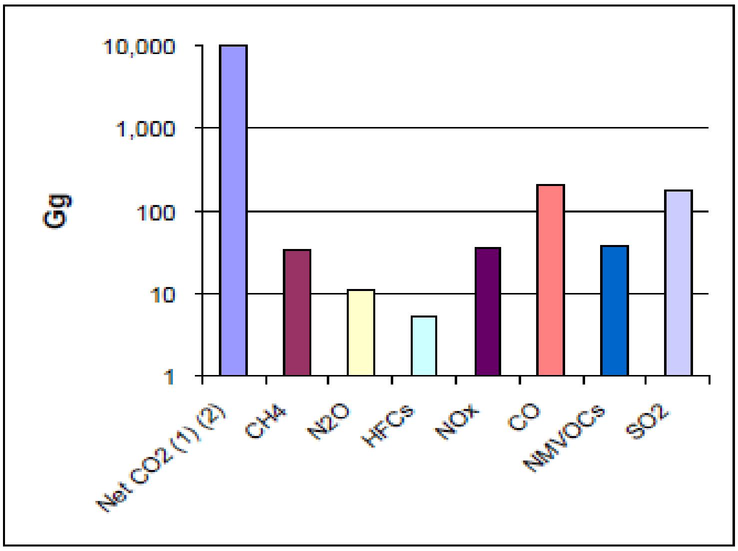


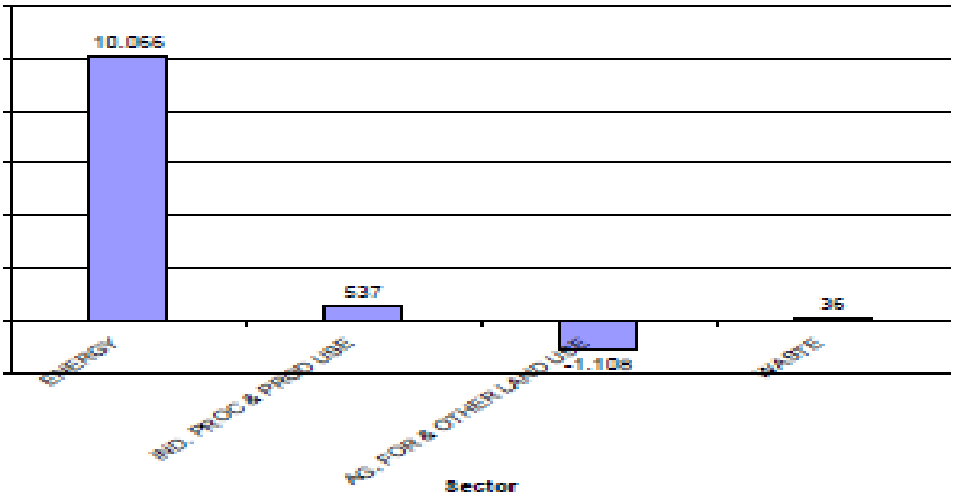
Table 2.1: Summary of National GHG Emissions in Jamaica (2000)

Table 1 Summary of Jamaica's Greenhouse Gas Emissions in 2000

	Categories	Net CO_2	CH_4	N_2O	HFCs	NOx	CO	NMVOCs	SO_2
		(Gg)			CO_2 Equivalents (Gg)	(Gg)			
	Total National Emissions and Removals	**9,532**	**31.7**	**9.86**	**4.13**	**34.0**	**191**	**23.9**	**173**
1	**ENERGY**	**10,066**	**3.77**	**1.23**		**34.0**	**191**	**20.0**	**171**
1A	Fuel Combustion Activities	10,062	3.77	1.23		34	191	19	171
1B	Fugitive Emissions from Fuels	4.21	7.31E-05	7.308E-06		0.00	0.00	1.46	0.00
1C	Carbon Dioxide Transport and Storage								
2	**INDUSTRIAL PROCESSES AND PRODUCT USE**	**537**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
2A	Mineral Industry	497	0.00	0.00					
2B	Chemical Industry	0.00	0.00	0.00					
2C	Metal Industry	0.00	0.00	0.00					
2D	Non-Energy Products from Fuels and Solvent Use	40.1	0.00	0.00					
2E	Electronics Industry	0.00	0.00	0.00					
2F	Product Uses as Substitutes for Ozone Depleting Substances	0.40	0.00	0.00	4.13				
2G	Other Product Manufacture and Use								
2H	Other								
3	**AGRICULTURE, FORESTRY AND OTHER LAND USE**	**-1,108**	**8.82**	**8.34**		**0.00**	**0.00**	**0.00**	**0.00**
3A	Livestock		8.82	0.19		0.00	0.00	0.00	0.00
3B	Land	-1,116	0.00	0.00					
3C	Aggregate Sources and Non-CO_2 Emissions Sources on Land	7.56	0.00230	8.16		0	0	0.00	0.00
3D	Other	0.00	0.00	0.00		0.00	0.00	0.00	0.00
4	**WASTE**	**36.3**	**19.1**	**0.1**	**0.0**	**0.0**	**0.3**	**3.9**	**1.4**
4A	Solid Waste Disposal		13	0.00					
4B	Biological Treatment of Solid Waste		0.00	0.00					
4C	Incineration and Open Burning of Waste	36.3	0.602	0.014	0	0	0.279	3.90	1.39
4D	Wastewater Treatment and Discharge	0.0	5.06	0.111	0	0	0	0	0
4E	Other (please specify)	0	0	0	0	0	0	0	0
5	**OTHER**	0	0	0.164	0	0	0	0	0
5A	Indirect N_2O Emissions from the Atmospheric Deposition of Nitrogen in NOx and NH_3	0	0	0	0	0	0	0	0
5B	Other (please specify)	0	0	0.164	0	0	0	0	0
	Memo items (5)								
	InternationalBunkers	**336**	**0.002**	**0.009**	**0.000**	**0.000**	**1.16**	**6.42**	**0.333**
	International Aviation (International Bunkers)	272	0.002	0.008		0	0.95	0.42	0.19
	International Water-borne Transport (International Bunkers)	64	0.000	0.002		0	0.21	6.01	0.14
	Multilateral Operations	0	0	0	0	0	0	0	0

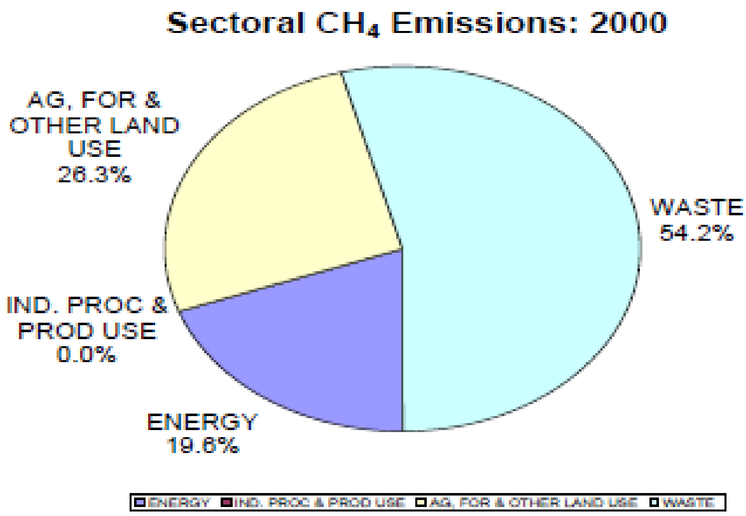
Net CO_2 emissions increased from 8,418 Giga-grams (Gg) in 1994 to 9,532 Gg in 2000. The energy sector accounted for nearly 86 per cent of the 2000 CO_2emissions, down from 97 per cent in 1994. The total estimated CO_2 removals (sinks) were 1,108 Gg in 2000, compared to 167 Gg in 1994. The Agriculture, Forestry and Other Land-Use sectors were responsible for the sink (Figure 2.2). However sufficient data (emission factors) were not available to determine the reasons for the large change – an apparent discrepancy. Total CO_2 emissions in 1994 were 8,585 Gg while in 2000 they had increased to 10,640 Gg.

Figure 2.2: Carbon Dioxide Emissions, by sector, in Jamaica (2000)



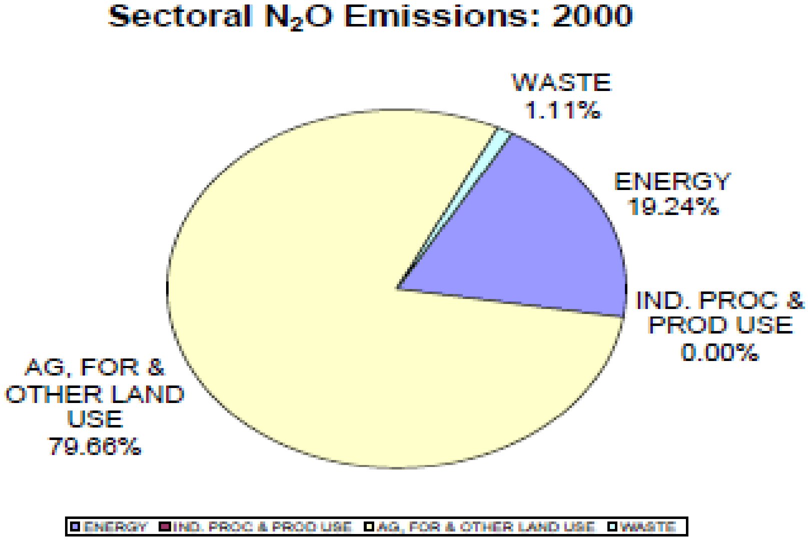
CH_4 emissions in 1994 were estimated at 58.5 Gg and 34.7 Gg in 2000. The estimates for CH_4 emissions in 2000 from enteric fermentation (36 Gg) and manure management (7 Gg) were considerably higher than those in 1994 (8.17 Gg and 0.646 Gg respectively). The waste sector accounted for 54% of the CH_4emissions in 2000, followed by Agriculture, Forestry and Other Land Uses (26%) and Energy (20%) (Figure 2.3).

Figure 2.3: Methane Emissions, by sector, in Jamaica (2000)



NO_2 emissions were estimated at 344 Gg in 1994 and 11.7 Gg in 2000. The reason for the large discrepancy between the 1994 and 2000 estimates could not be determined since raw data used in the 1994 calculations were not available. Managed soils (fertilizer applications) accounted for 80% of the NO_2emissions (Figure 2.4).

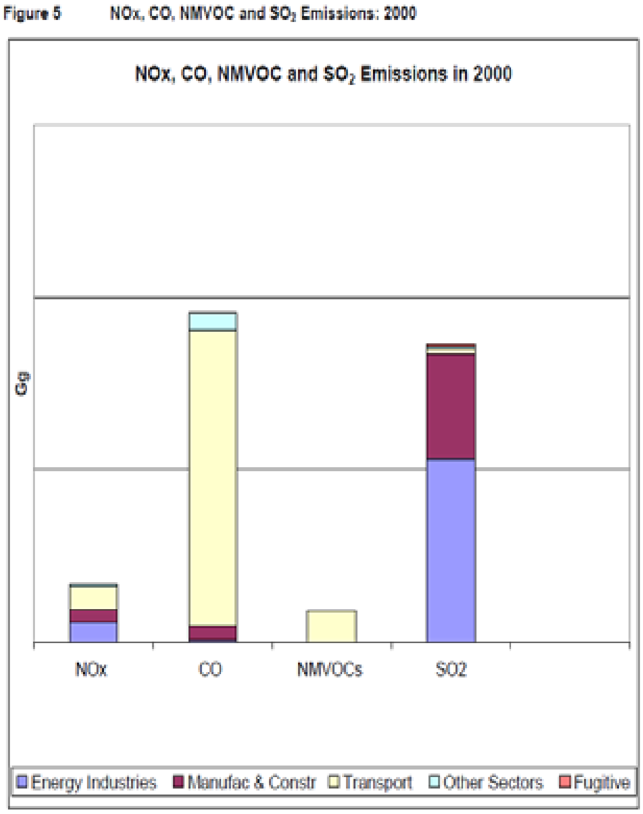
Figure 2.4: Nitrous Oxide Emissions, by sector, in Jamaica (2000)



Estimates for Hydrofluorocarbons emissions were not made in 1994 but were 5.16 Gg in CO_2 equivalents in 2000.

NOx emissions were estimated at 30.9 Gg in 1994 and 35.9 Gg in 2000 (Figure 2.5). CO, NMVOCs, and SO_2 emissions in 1994 were 173 Gg, 29.1 Gg and 98.9 Gg respectively; these rose to 205 Gg, 27.6 Gg and 173 Gg respectively in 2000. The transport sector accounted for the majority of CO and NMVOC emissions. The energy industries (electricity generation) and manufacturing categories accounted for the majority of SO_2 emissions.

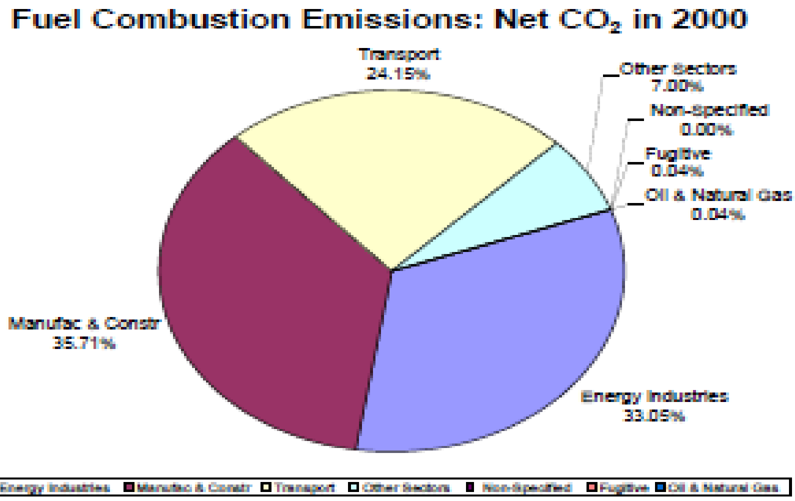
Figure 2.5: Emissions of Indirect Greenhouse Gases in Jamaica (2000)



Selected features of the sub-sectoral contributions to the GHG inventory in 2000 are as follows:

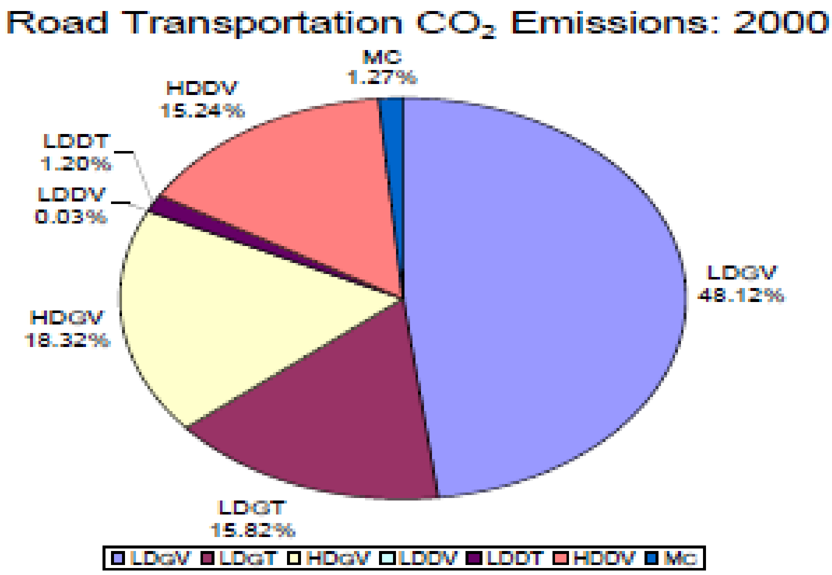
- Manufacturing and construction accounted for 35.7 per cent of net CO_2 fuel combustion emissions, followed by energy industries (electricity generation and petroleum refining), 33.1 per cent, and transport, 24.2 per cent (Figure 2.6). It should be noted that manufacturing and construction includes some (but not all) components of the bauxite alumina industry.

Figure 2.6: Net Carbon Dioxide Emissions from Fuel Combustion in Jamaica (2000)



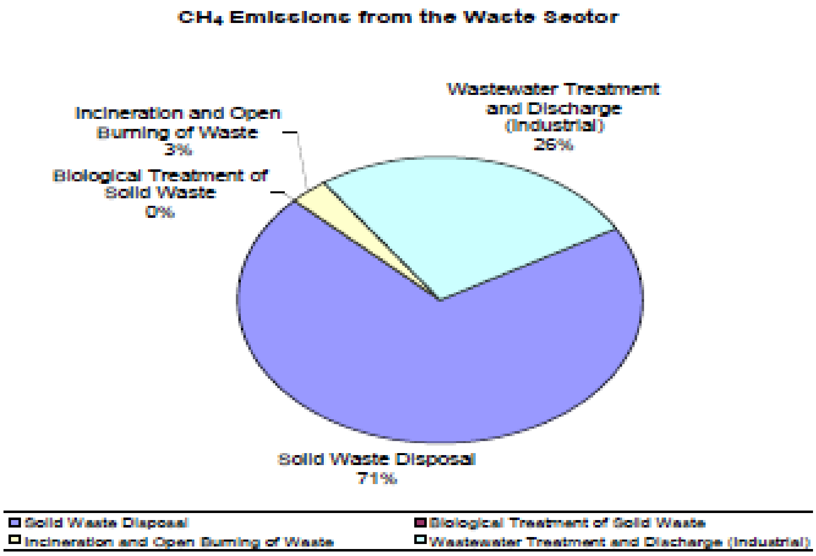
- In the transport sector (Figure 2.7), light duty gasoline vehicles accounted for 48% of the CO_2 emissions, with similar contributions (15 to 18%) from light duty gasoline trucks (LDGT), heavy duty diesel vehicles (HDDV) and heavy duty gasoline (HDGV) vehicles.

Figure 2.7: Carbon Dioxide Emissions from On-Road Transportation in Jamaica (2000)



- CH_4 emissions from the waste sector were mainly from solid waste disposal (71%) followed by wastewater treatment (26%) (See Figure 2.8).

Figure 2.8: Methane Emissions from the Waste Sector in Jamaica (2000)



2.2.2 Trends between 2000 and 2005

The methodologies used in compiling the current inventory (according to the IPCC 2000 Guidelines) are different from those used to compile the 1994 inventory. Archived activity data for the 1994 inventory were incomplete (especially for the agriculture and forestry sectors) and hence it was not feasible to reconstruct the 1994 inventory using the 2006 methodologies. Because of this, trends in emissions are discussed only for 2000-05.

Overall, annual emissions for CO_2, CH_4 and N_2O all showed an increasing trend from 2000-05, as shown in Figure 2.9, with only a minor drop in 2004.

CO_2 emissions increased consistently from 9,531 Gg in 2000 to 13,956 Gg in 2005. The large (46%) increase in CO_2emissions in the energy sector was due to increases in fuel consumption in the manufacturing (bauxite and alumina industry) and transportation categories (Figure 2.10). There was little change in the magnitudes of the sources and sinks for CO_2in the Agriculture, Forestry and Other Land Use sectors between 2000 and 2005.

In the Industrial Processes and Products Use Sector, the CO_2emissions from the cement industry increased over 2000-05 but those due to lime manufacture declined (Figure 2.11). Importation of lime was required to meet the alumina industry demands.

CO_2emissions in the waste sector increased over 2000-05. The contribution from managed disposal sites decreased while that from unmanaged sites increased (see Figure 2.12). There was a similar pattern for CH_4 emissions in the waste sector. Overall, CH_4 emissions rose from 31.1 Gg in 2000 to 41.9 Gg in 2005.

Figure 6 CO_2 , N_2O and CH_4 Emissions: 2000 to 2005

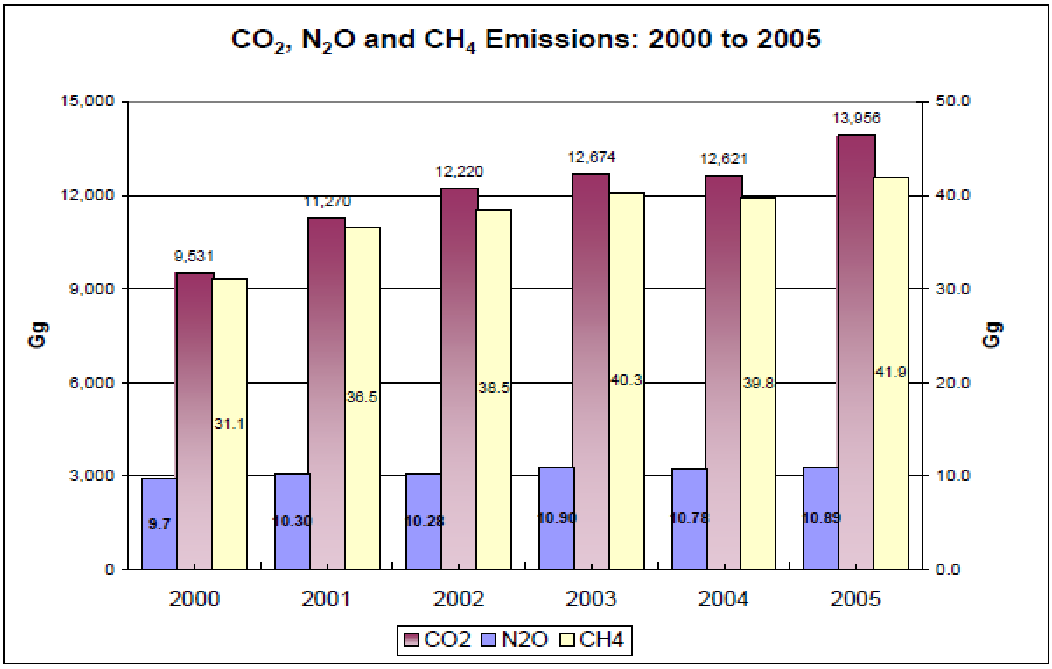


Figure 7 Energy Sector CO_2 Emissions: 2000 to 2005

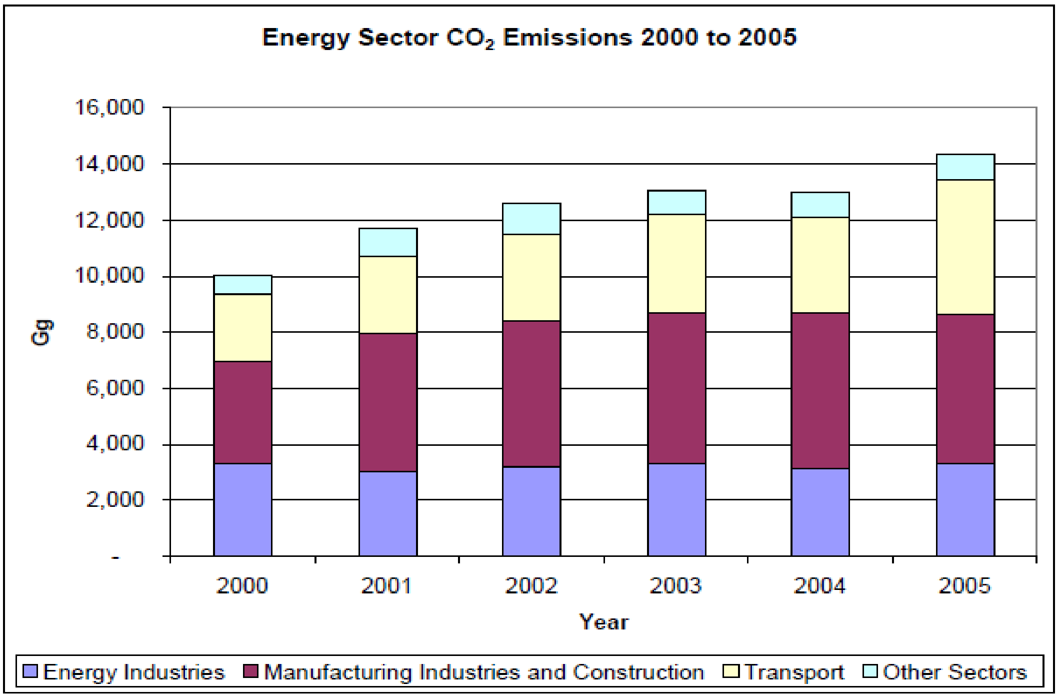


Figure 8 Industrial Processes and Product Use CO_2 Emissions: 2000 to 2005

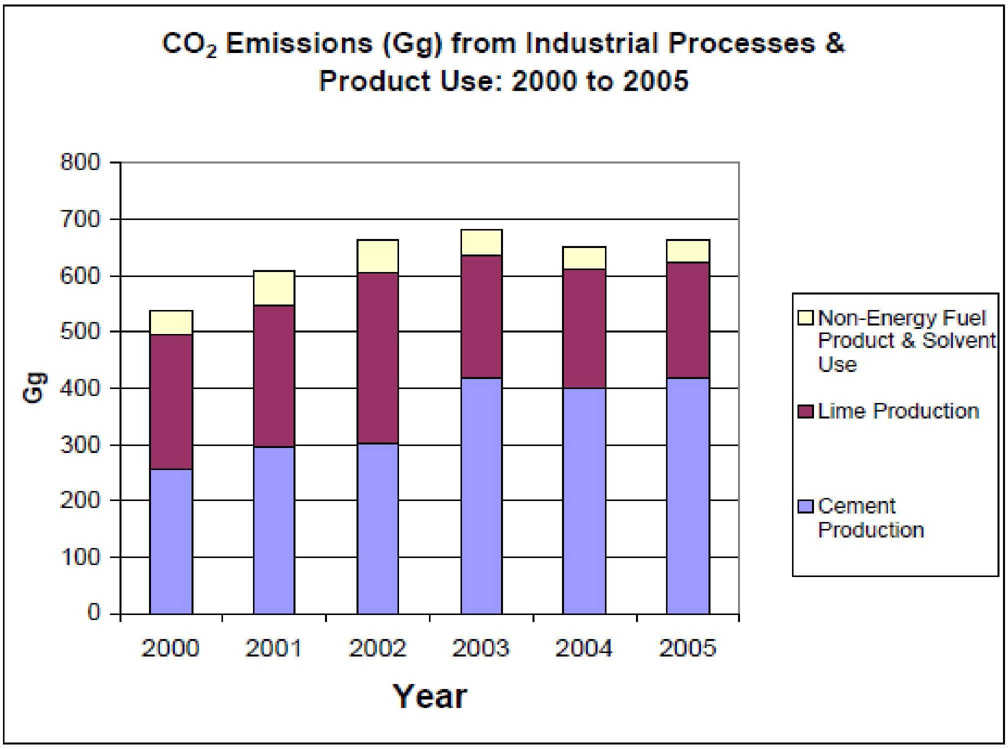
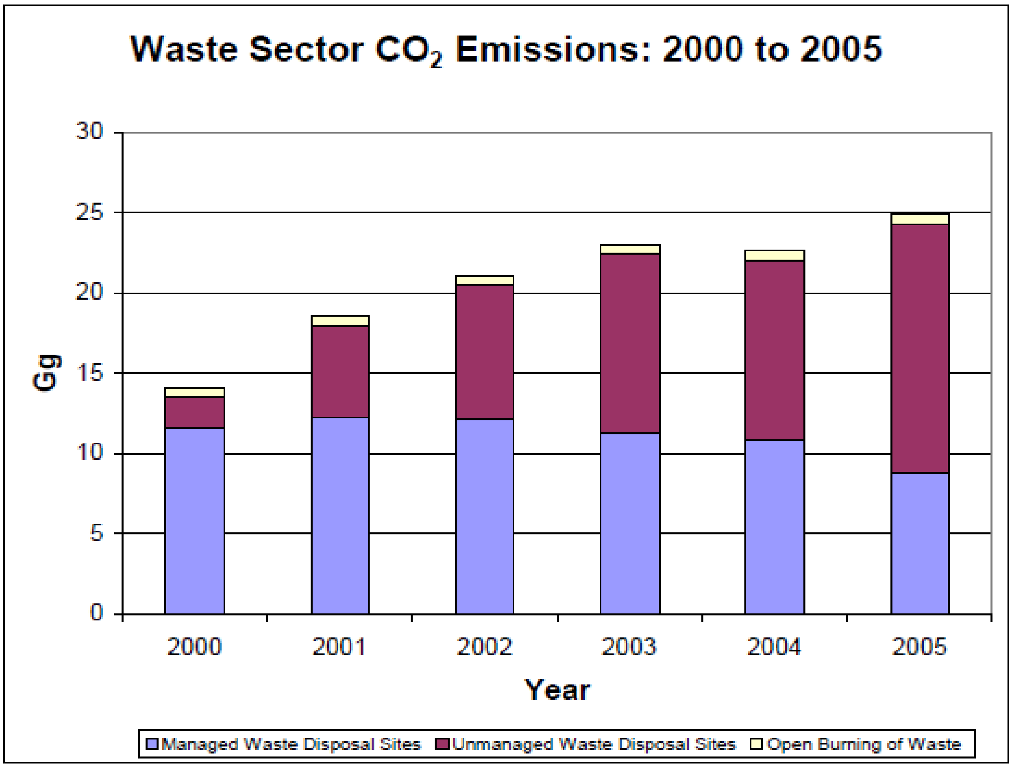


Figure 9 Waste Sector CO_2 Emissions: 2000 to 2005



2.2.3 Uncertainties

Uncertainties in the overall GHG inventory for emission factors and activity data were calculated using the 2006 IPCC Guidelines. The Guidelines recommend evaluation of the uncertainties in the annual estimates as well as in trends. This was done for the 2005 inventory using 2000 as the base year; estimates of the uncertainty alone were made for 2000.

The overall uncertainties in the 2000 and 2005 inventories were about 10%, while the uncertainty in the trend between 2000 and 2005 was 16%. CO_2 accounted for between 70 and 77% of the emissions on a CO_2equivalent basis. Most of the CO_2emissions are from fuel combustion which, apart from some transportation categories, in general has low uncertainties.

<u>Conclusion</u>

Improvements to the GHG inventory will greatly facilitate the core business of data suppliers. This is especially true of the energy sector/fuel use data where reliable energy end use information is so critical in identifying opportunities for improving energy efficiency and reducing fuel use.

2.3 Energy Sector Greenhouse Gas Emissions

The energy sector consists of the following types of activities (source categories):

- Exploration and exploitation of primary energy sources,
- Transmission and distribution of fuels,
- Conversion of primary energy sources into more useable energy forms in refineries and power plants, and
- Use of fuels in stationary and mobile applications.

Emissions arise from these activities by combustion and as fugitive emissions, or escape without combustion.

There is no primary energy industry in Jamaica, so this source category was not considered in the energy sector. The source categories covered in the Energy Sector and those that are present in Jamaica and therefore relevant for the inventory are summarized in Table 2.2. The sources that are present in Jamaica are indicated by a “Y” or “*”. In the former case (Y), the inventory includes a specific worksheet to identify emissions while in the latter case (*) the emission estimates are included in another sector (because data were not available to disaggregate the emissions).

Table 2.2: Energy Sector Source Categories Present in Jamaica

Category Code	Category Name	Present In Jamaica#
1A1	**Fuel Combustion Activities – Energy Industries**	
1A1a	Main Activity Electricity and Heat Production	Y
1A1b	Petroleum Refining	Y
1A1c	Manufacture of Solid Fuels and Other Energy Industries	N
1A2	**Fuel Combustion Activities - Manufacturing Industries and Construction**	
1A2a	Iron and Steel (ISIC Group 271 and Class 2731)	N
1A2b	Non-Ferrous Metals (ISIC Group 272 and Class 2732)	N
1A2c	Chemicals (ISIC Division 24)	Y
1A2d	Pulp, Paper and Print (ISIC Divisions 21 and 22)	N
1A2e	Food Processing, Beverages and Tobacco (ISIC Divisions 15 and 16)	*
1A2f	Non-Metallic Minerals (ISIC Division 26)	Y
1A2g	Transport Equipment (ISIC Divisions 34 and 35)	N
1A2h	Machinery (ISIC Divisions 28 to 32)	N
1A2i	Mining (excluding fuels) and Quarrying (ISIC Divisions 13 to 14)	Y
1A2j	Wood and Wood Products (ISIC Division 20)	*
1A2k	Construction (ISIC Division 45)	*
1A2l	Textile and Leather (ISIC Divisions 17, 18 and 19)	*
1A2m	Non-specified Industry	Y
1A3	**Mobile Combustion (Transport)**	
1A3a	Civil Aviation	Y
1A3b	Road transport	Y
1A3c	Railways	Y
1A3d	Waterborne Navigation	*
1A3e	Other Navigation	*
1A4	**Fuel Combustion Activities – Other Sectors**	
1A4a	Commercial / Institutional	Y
1A4b	Residential	Y
1A4c	Agriculture / Forestry / Fishing / Fish Farms (Stationary combustion)	*
1A5	**Fuel Combustion Activities – Non-Specified**	**N**
1A5a	Non-Specified Stationary	*
1B	**Fugitive Emissions from Fuels**	
1B1	Fugitive emissions from fuels - Solid Fuels	N
1B2	Oil and Natural Gas	
1B2a	Fugitive Emissions from Fuels – Oil and Natural Gas – Oil	Y
1B2b	Fugitive Emissions from Fuels – Oil and Natural Gas - Natural gas	N
1B3	Other emissions from Energy Production	
1C	**Carbon Dioxide Transport and Storage**	**N**
1D	**Miscellaneous**	**N**

2.3.1 Fuel Combustion Activities - Energy Industries (1A1)

For Jamaica, this sub-sector comprises electricity and heat production (1A1a), petroleum refining (1A1b) and the manufacture of charcoal (1A1c). Emission estimates from these sub-sectors are described below. For all calculations in the energy sector, the default values for the net calorific values, carbon content and CO_2 emission factors found in the 2006 IPCC Guidelines were used. Emissions data for the energy Industries sub-sector are summarized in Table 2.3.

Table 2.3: Summary of Emissions from the Energy Industries Sector (Fuel Combustion) (Gg) (2000)

	CO_2	CH_4	N_2O	NOx	CO	NMVOCs	SO_2
1 ENERGY	10,066	6.91	2.17	35.20	201	20.2	173
1A Fuel Combustion Activities	10,062	7	2	35	201	19	173
1A1 Energy Industries	3,329	0.26	0.05	11.64	1.21	0.08	106.06
1A1 a Main Activity Electricity and Heat Production	3,280	0	0	6	1	0	53
1A1 ai Electricity Generation	3,280	0.13	0.03	5.80	0.60	0.04	52.60

<u>Electricity and Heat Production (1A1a)</u>

Electricity for public consumption is supplied by the Jamaica Public Service Company (JPS) which is also the main generator of electricity in Jamaica. JPS purchases electrical power from several other independent sources. These include Jamaica Energy Partners (JEP) and Jamaica Private Power Company (JPPC), which are dedicated private power producers, and also other facilities that produce electricity for their own use and sell the excess to JPS. The GHG emissions from the production of heat and own-use by industry are included in the industrial processes sector emissions.

Between 2000 and 2005, purchased power was between 25.6% and 30.5% of the total output (3.30 to 3.87 GWh). The annual fuel use for electricity generation between 2000 and 2005 ranged from 5,159,687 to 4,811,726 million barrels of heavy fuel oil and from 725,158 to 1,794,870 million barrels of diesel oil. Activity data (fuel consumption) were obtained from the Ministry of Energy, Mining and Telecommunication (MEMT), and private power producers.

Estimates of fuel use and emissions from cogeneration were based on data provided by JBI (fuel consumption and electricity sales) and efficiency data provided by the company. Emissions from the electricity generation source category between 2000 and 2005 ranged from 2,977 Gg to 3,365 Gg for CO_2 (Figure 2.10), 0.116 Gg to 0.132 Gg for methane, and 0.023 Gg to 0.026 Gg for N_2O.

<u>Petroleum Refining (1A1b)</u>

Fuels used by refineries in refining crude oil are included in the energy sector. The refinery used heavy fuel oil, refinery gas, kerosene, automotive diesel oil and propane in its operations. The amounts of fuels used in refinery operations were obtained from Petrojam and MEMT. In 2000, the energy use by Petrojam amounted to 271,373 TJ (42,514 fuel oil equivalent barrels (FOEB) i and resulted in emissions of 15.1 Gg of CO_2 and negligible amounts of CH_4 (6 x 10-4 Gg) and N_2O (1.2 x 10-4 Gg).

2.3.2 Fuel Combustion Activities - Manufacturing Industries And Construction (1A2)

The main manufacturing industries present in Jamaica are Chemicals (Alumina), Non-Metallic Minerals, Mining (excluding fuels) and Quarrying. Activity data (fuel consumption) for food and beverage, textiles are not compiled routinely, and hence emissions from these sub-sectors are included in Non-Specified Industry. Emissions from the industry sector are based on sub-categories that correspond to the International Standard Industrial Classification of all Economic Activities (ISIC) – see Table 2.4. Since fuel use data were available for the sugar industry, data are reported separately for sugar, cement and lime manufacture.

Table 2.4: GHG Emissions from Fuel Combustions in Manufacturing Industries (2000)

	CO_2	CH_4	N_2O	NOX	CO	NMVOCs	SO_2
1A2 -Manufacturing Industries and Construction	3.597	0.253	0.043	7.35	8.24	0.31	60.9
1A2c - Chemicals	2.956	0.115	0.023	5.17	0.54	0.08	50.90
1A2e - Food Processing, Beverages and Tobacco (Sugar)	60	0.116	0.016	1.28	7.59	0.19	3.50
1A2f – Non-Metallic Minerals	381	0.014	0.003	0.53	0.07	0.02	4.70
1A2i - Mining (excluding fuels) & Quarrying	112	0.004	0.001	0.21	0.02	0.00	1.00
1A2m- Non-specified Industry	87	0.003	0.001	0.16	0.02	0.00	0.90

Chemicals – Alumina Production (1A2c)

Alumina production (ISIC 2420) is the dominant fuel use sector in Jamaica. The reporting of fuels use data for the alumina industry is made along with that for bauxite mining and, in some cases, lime production. The reported data allowed disaggregation of fuel use in alumina production – i.e., for boilers (steam used in alumina production and own-use electricity generation) and kiln drying of alumina. In some cases, the reported data included heavy fuel oil used for lime manufacture which was isolated and reported under lime manufacture.

Gasoline use in the bauxite and alumina industry was allocated to road transportation. The reported diesel fuel use in the alumina industry included uses for alumina processing, rail and road transportation and mining and all of these uses were not always reported separately. In those cases the diesel fuel use for mining and rail transportation was allocated based on bauxite production and other information (see sections on mining and rail transportation) in order to estimate the diesel fuel used for alumina processing.

It was assumed that there was negligible diesel fuel use for road transportation in the reported data from alumina companies (i.e., all diesel fuel was used for mining, rail transportation and alumina processing). Fuel use data for the bauxite and alumina sectors were obtained from the Jamaica Bauxite Institute (JBI) and MEMT and production data were also obtained from JBI. There were discrepancies in the diesel fuel use from these sources which were likely due to the manner in which fuel used for mining was accounted for. In some years, some companies used a contractor for mining and fuel sales to the contractor were not always reported in the alumina industry reports.

Sugar Industry (1A2e)

The energy requirements for the manufacture of sugar from sugar cane are derived from renewable sources (bagasse, wood) as well as from heavy fuel oil. Best practices in the sugar industry entail the use of bagasse for all factory (steam and electricity) needs with excess energy used to supply electricity to the public grid. The isolation of heavy fuel oil (to supplement bagasse) in many of Jamaica's sugar factories allows the identification not only of the GHG emissions associated with heavy fuel oil combustion in the sugar industry, but also the potential for eliminating heavy fuel oil use if bagasse were in sufficient supply. The CO_2 emissions from the renewable fuels (bagasse and wood) are noted as memo items and are not included in the national CO2 emissions.

Non-Metallic Minerals (1A2f)

This sub-sector comprises cement and lime manufacture. The major uses of lime in Jamaica are in the alumina industry and in sugar refining. Fuel use data were obtained from MEMT and JBI and Caribbean Cement Company Limited (CCCL) and one of two lime manufacturing plants (Chippenham Park Ltd.).

Mining and Quarrying (1A2i)

Mining of bauxite is the major activity in this sector. There is also quarrying for limestone (for cement and lime manufacture), shale and gypsum (for cement manufacture), and marl and sand (for road and building construction). Fuel use data are compiled and reported for the bauxite and alumina industries but data are not available to allow estimates of fuel use for the remaining activities. Most of the fuel used in quarrying is associated with the transportation of materials and is captured in the transportation sub-sector. The estimates for mining reported here are only for the bauxite mining.

Three of the four bauxite and alumina industry companies produce both bauxite and alumina and the fourth company mines bauxite exclusively. In the latter case, bauxite is dried using heavy fuel oil to fire bauxite drying kilns. All heavy fuel oil and diesel fuel use reported for the bauxite-exclusive company was attributed to mining. It was assumed that none of this diesel fuel use was attributable to road transportation. For companies with bauxite mine and alumina refineries, diesel fuel is used for off-road mining equipment and for transporting bauxite to railheads or alumina to ports as well as for refinery-related activities.

Diesel fuel use for mining in these cases was estimated from the total fuel use less that for all boilers, rail transportation and port related activities. For some years and companies, mining was subcontracted to a third party company whose fuel use may not have been captured within the bauxite/alumina sector by MEMT or JBI.

Non-specified Industry (1A2m)

Activities included in this sector consist of all manufacturing other than those described above. It includes food and beverage industries, leather, chemical (sulphuric acid and other chemicals) and construction. Fuel use data are compiled by MEMT for this sub-sector. Emissions from the Fuel Combustions in Manufacturing Industries sub-sector for the year 2000 are indicated in Table 2.4.

2.3.3 *Mobile Combustion (Transportation) Sector (1A3)*

The transportation sector includes emissions from on-road and off-road mobile sources, aviation, railways and water-borne navigation. Fuel combustion in mobile sources produces the direct GHGs (CO_2, CH_4, N_2O) as well as the indirect GHGs (CO, NMVOCs, SO_2, PM and NOx). Fuel use for the aviation and marine sources do not include fuel delivered to international bunkers. Emissions from the transport sector are given in Table 2.5. The transport sector – and especially the on-road vehicle fleet – is a major source category and hence considerable effort was made to obtain the best estimates.

Table 2.5: GHG Emissions (Gg) from the Transport Sector (2000)

	CO_2	CH_4	N_2O	NOx	CO	NMVOCs	SO_2
1A3 Transport	2,432	3.26	1.13	15.0	181	18.2	4.63
1A3 a Civil Aviation	281	0.002	0.008	0.98	0.64	0.20	0.027
1A3 ai International Aviation (International Bunkers) (1)	272	0.002	0.008	0.952	0.415	0.191	0.000
1A3 aii Domestic Aviation	9	0.000	0.000	0.032	0.222	0.010	0.027
1A3 b Road Transportation	2,051	0.116	0.164	12.6	164	17.3	3.15
1A3 bg LDGV Passenger cars (gasoline)	987	0.056	0.084	4.42	91.8	11.2	0.902
1A3 biig12 LDGT12 Light Duty Trucks12 (gasoline)	273	0.015	0.023	0.962	25.7	2.58	0.249
1A3 bii g34LDGT34 Light Duty Trucks34 (gasoline)	51	0.003	0.004	0.168	5.03	0.488	0.047
1A3 biig LDGT Light Duty Trucks all (gasoline)	324	0.018	0.028	1.13	30.8	3.07	0.296
1A3 biiig HDGV Heavy Duty Trucks (Gasoline)	376	0.021	0.032	2.87	36.4	1.60	0.350
1A3 bd LDDV Passenger cars (diesel)	0.70	0.000	0.000	0.003	0.00	0.001	0.003
1A3 biid LDDT Light Duty Trucks (diesel)	24.6	0.001	0.001	0.064	0.06	0.030	0.115
1A3 biiig HDDV Heavy Duty Trucks (diesel)	313	0.017	0.017	3.97	1.57	0.381	1.46
1A3 biv MC Motorcycles	26.0	0.001	0.002	0.138	3.53	1.04	0.024
1A3 c Railways	24.3	0.001	0.009	0.393	0.33	0.065	0.046
1A3 d Water-borne Navigation	75.6	0.000	0.002	0.249	6.01	0.142	0.000
1A3 di International Water-borne Navigation (International Bunkers) (1)	64.3	0.000	0.002	0.212	6.01	0.142	0.000
1A3 dii Domestic Water-borne Navigation	11.3	0.000	0.000	0.037	0.00	0.000	0.000
1A3 eii Off-road	0.0	0.000	0.000	0.000	0.00	0.000	0.000

Civil Aviation (1A3a)

Aviation emissions from the use of jet fuel and aviation gasoline include CO_2, smaller amounts of NOx, CO, SO_2, NMVOC and particulate matter, and much smaller amounts of CH_4 and N_2O.

Aircraft emissions are generally disaggregated into emissions during landings and take-offs (LTOs) and cruising mode. Aviation emissions relevant to Jamaica are those for International Aviation (category 1A3ai) and Domestic Aviation (1A3aii).

Aviation jet fuel use data for Jamaican military were available to estimate emissions category 1A5b (Mobile aviation not specified elsewhere). However, since LTO data for Jamaican military flights (except for movements for Up Park Camp airstrip) were included in the aircraft movement data for other airports, a separate estimate for category 1A5b was not made.

Aggregate data for the airports were available from the Civil Aviation Authority (CAA) web site and these data were compared with the individual LTO data provided by Airports Authority of Jamaica (AAJ). The discrepancies were assumed to be equal to the number of touch-and-go flights since these were not captured in the AAJ database for 2003-05. The AAJ data at the Norman Manley International Airport (NMIA) for 2001 and 2002 included the number of touch-and-go LTOs. The available data for the international airports are summarized in Table 2.6.

Table 2.6: Available LTO data at Jamaica's International Airports (2000-05)

Airport		Total Movements		DISCREPANCY IN ARRIVALS
		AAJ Data	CAA Web Site	CAA - Arrivals - Touch & Go
Sangster Intl #	2000	58450	61116	2666
Sangster Intl #	2001	64490	68535	4045
Sangster Intl #	2002	63162	66518	3356
Sangster Intl	2003	49058	60076	5473
Sangster Intl	2004	56371	57862	714
Sangster Intl	2005	52095	52942	373
Norman Manley Intl	2000	NA	39981	0
Norman Manley Intl	2001	35869	39296	3427
Norman Manley Intl	2002	32121	39678	7557
Norman Manley Intl	2003	22377	27891	2887
Norman Manley Intl	2004	20374	24481	2131
Norman Manley Intl	2005	21188	25994	2456

Individual aircraft movement data (i.e., arrivals and departures separately) for domestic and international flights were available only for 2003 to 2005 (shaded area in Table 2.7).

Table 2.7: Available LTO data at Jamaica's Domestic Aerodromes (2000-05)

		Arrivals				
	2000	2001	2002	2003	2004	2005
KTP	4,410	3,698	2,870	7,671	11,060	10,122
NEG	9,314	12,399	11,272	4,627	6,007	5,818
OCJ	4,007	4,042	4,295	2,887	4,597	4,198
POT	3,796	3,214	2,560	915	1,263	1,067
SIA	NA	NA	NA	9,175	12,508	12,557
NMIA	NA	NA	NA	1,949	1,742	2,120

Only aggregate movement data were available otherwise. Although some individual LTO data were available for Sangster International Airport (SIA) and NMIA for 2000 to 2002, the data provided did not include points of origin or destination in order to determine which flights were domestic.

The estimates of emissions from domestic flights for 2000 to 2002 were assumed to be the same as in 2003. Sales of aviation fuels (jet fuel and aviation gasoline) to locally registered airlines were reported as domestic consumption (see Table 2.8).

Table 2.8: Aviation Fuel Sales (2000-05)

	Sales to Domestic Airlines (bbl)		Sales to International Airlines (bbl)	
Year	Aviation Gasoline	Jet Kerosene	Aviation Gasoline	Jet Kerosene
2000	4,612	836,543	438	655,978
2001	4,683	525,479	870	911,478
2002	4,580	535,811	372	1,076,110
2003	2,200	39,782	1,000	1,577,161
2004	3,110	86,708	0	1,703,157
2005	5,700	18,283	0	1,553,455

Sales to international airlines are recorded as international bunkers. This appears to have been the case in 2000-02, but may not have been so for 2003-05 for jet fuel. The majority of the domestic jet fuel sales would have been to Air Jamaica, which uses the bulk of such fuel on international flights, but the airline also operates flights between the two international airports. Consequently the fuel estimates (LTO and cruising) between the two Jamaican international airports were subtracted from the total jet fuel sales and the remainder was attributed to international bunkers. Estimates (preliminary) for aviation emissions (without any correction for fuel use during domestic Air Jamaica flights) in 2000 are given in Table 2.9.

Table 2.9: Summary of Aviation Emissions (2000)

	CO_2	CH_4	N_2O	NOx	CO	NMVOCs	SO_2
1A3 Transport	2,432	3.26	1.13	15.0	181	18.2	4.63
1A3 a Civil Aviation	281	0.002	0.008	0.98	0.64	0.20	0.027
1A3 ai International Aviation (International Bunkers) (1)	272	0.002	0.008	0.952	0.415	0.191	0.000
1A3 aii Domestic Aviation	9	0.000	0.000	0.032	0.222	0.010	0.027

LTO emissions estimates for domestic flights (Table 2.10) were made based on emission factors obtained from the United States Federal Aviation Administration (FAA) Emissions & Dispersion Modeling System (EDMS) model (Version 5.1). LTO data were reviewed to determine aircraft types in the many cases where codes did not match International Civil Aviation Organization (ICAO) Codes. LTO emissions of CO, THC, NMHC, VOC, NOx, SOx, PM10 and PM2.5 were estimated for all domestic flights. The model output also includes fuel used and this was used to estimate the carbon dioxide emissions. The model default taxi and queue times were changed to 5 minutes in and out for domestic aerodromes and 5 minutes in and 7 minutes out for the international airports.

Table 2.10: Summary of Domestic LTO Emissions and Fuel Use (2003-04)

	LTO Emissions (Gg)							Fuel (kg)	
Year	CO_2	CH_4	N_2O	NOx	CO	NMVOC	SO_2	Turbo Fuel	AvGas
2003	8.99	5.6E-05	2.2E-04	0.032	0.139	0.033	0.127	2,539,493	316,775
2004	10.10	5.5E-05	2.2E-04	0.032	0.214	0.029	0.125	2,482,258	731,603

Domestic cruise emission estimates require information on the routes flown between the local airports, the number of such flights, the types of aircraft used and the amount of fuel used. The cruise emissions and fuel use for domestic flights were obtained from the EMEP/CORINAIR 2007 Guidebook, using SNAP97 Codes 080503 and 080504. The database includes fuel use and cruise emissions for cruise distances starting from 125 nautical miles (nm).

The distances between each of the local aerodromes or airports is less than 125 nautical miles. Hence estimates of fuel use and emissions were made by linear extrapolation from the four lowest distances provided in the EMEP/CORINAIR database. Cruise data (fuel consumption and emission rates) were available for some but not all of the aircraft used in domestic flights (e.g., Airbus 300 series, Dash 8 and some Cessnas). For the remaining aircraft, fuel consumption data were matched to the data in the CORINAIR database; otherwise the engine fuel consumption for the approach cycles multiplied by the number of engines (available from the ICAO engine database) and the average travel times between airports was used as a surrogate for cruise emissions. Estimates of cruise emissions are given in Table 2.11.

Table 2.11: Summary of Domestic Cruise Emissions and Fuel Use (2003-05)

	Cruise Emissions (Gg)							Fuel (kg)	
Year	CO_2	CH_4	N_2O	NOx	CO	NMVOC	SO_2	Turbo Fuel	AvGas
2003	22.0	1.5E-04	6.0E-04	0.074	0.029	0.015	0.003	6,581,704	89,861
2004	18.3	1.3E-04	4.7E-04	0.057	0.023	0.011	0.003	4,993,363	148,430

When aircraft data were available in the EMEP/CORINAIR database, estimates for CO_2, NOx, CO and THC (assumed to be the same as NMVVOC) were made. Otherwise fuel based emission factors were used.

Road Transportation (1A3b)

The Road Transportation sub-sector includes all types of light-duty vehicles such as automobiles and light trucks, and heavy-duty vehicles such as trucks, tractor trailers and buses and on-road motorcycles. These vehicles operate on liquid (gasoline and diesel) and gaseous (propane or liquefied petroleum gas) fuels. The use of gaseous fuels in Jamaica is negligible and was omitted from further consideration. The GHGs emitted from fuel combustion in road transportation are CO_2, CO and NOx as well as emissions associated with catalytic converter use (NOx, N_2O, and CH4) or vehicle operation (NMVOCs, PM).

Although road transport is a key sector for Jamaica, it was not feasible to collect historical country-specific fuel (gasoline and diesel) carbon content data (as required for Tier 2), hence the Tier 1 method was used to estimate CO2 emissions based on fuel consumption. Default emission factors were used.

Fuel use data are collected by MEMT and while data for gasoline will reliably reflect use in vehicles (since other uses of gasoline are relatively small), the same cannot be said for diesel. Gasoline consumption data include uses for marine, standby generators and off road uses and these amounts are likely to be a small percentage of the total consumption. The consumption data for diesel attributed to transportation likely includes uses for marine and off-road uses but these would be a larger percentage of diesel sales. These factors would lower the on-road consumption data derived from MEMT reports. In contrast, diesel consumption for some sectors (bauxite, government and others) will include on-road fleet uses.

CH_4 and N_2O emissions are dependent on vehicle technology, fuel and operating characteristics. The Tier 1 method entails using fuel-specific emission factors for CH_4 and N_2O. Where the amounts of fuels sold can be broken down by vehicle type, a Tier 2 method can be used.

Vehicle type should preferably be further split by vehicle age to enable categorization of vehicles by control technology (e.g., by inferring technology adoption as a function of policy implementation year). Since the sulphur content of fuels did not change over the inventory period it was not necessary to account for the dependence of the emission control system on the fuel sulphur content.

Methodology used to Estimate On-Road Emissions

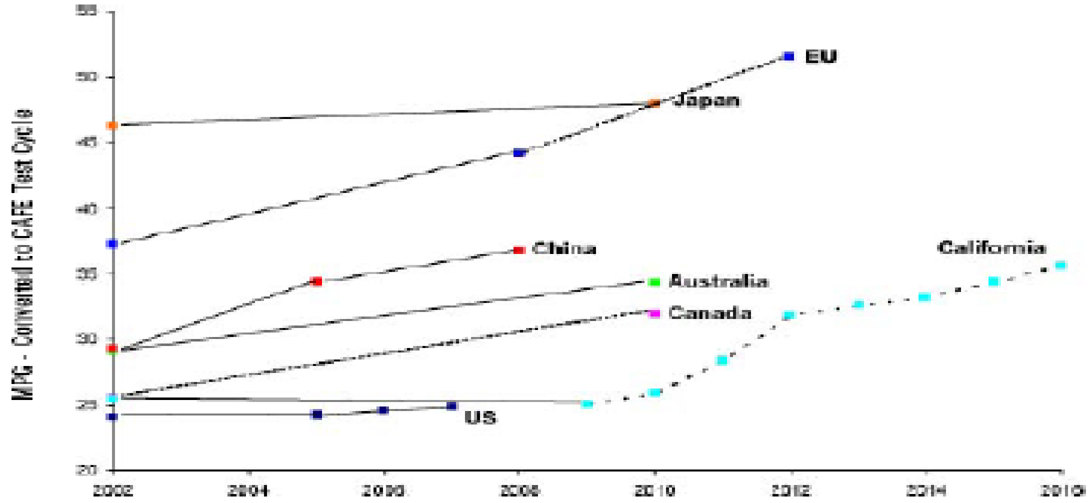
Detailed fleet information was obtained in order to apply a model (*MOBILE6*) to estimate emissions of CO_2, NMVOC, NOx, SO_2 and CO according to a Tier 3 method. The model does not provide estimates for CH_4 and N_2O; hence default emission factors and fuel use data were used to estimate these emissions. The *MOBILE6* software was developed by the United States Environmental Protection Agency (US EPA) to provide estimates of current and future emissions from highway motor vehicles. *MOBILE6* calculates average in-use fleet emission factors for various pollutants including NMVOC, CO, NOx, and CO2, SO_2, and brake wear particulate matter. Emissions can be estimated for gasoline, diesel and natural-gas-fuelled cars, trucks, buses and motorcycles manufactured between 1952 and 2050.

The user-specified model inputs include climate and geographic related parameters (altitude, temperature), fuel characteristics, fleet information (age distribution, vehicle weight classes, vehicle miles travelled, number and duration of trips by vehicle class) road characteristics, average vehicle speeds and specification of the types of outputs needed. The model also includes a number of assumptions that are “hard wired” and are specific to the US fleet. The most important of these include emission rates for various vehicle classes which were developed based on the introduction of US emission and evaporative standards. Such standards were not applicable to Jamaica since the majority of the Jamaican fleet is of Japanese origin.

Emission standards were not easily compared because of differences in the test drive cycles, units of measurement and policy approaches. However, a methodology developed to determine the relative stringency of fuel economy and GHG emission standards found that European Union (EU) and Japanese standards were the most stringent of nine automobile market regions that were compared[11] (Figure 2.14).

[11] An, F. and Sauer, A. (2004) Comparison of Passenger Vehicle Fuel Economy and Greenhouse Gas Emission Standards Around The World Prepared for the Pew Centre on Global Climate Change.

Figure 2.14: Comparison of Fuel Economy and GHG Emission Standards Normalized by CAFÉ-Converted mpg (From An & Sauer (2004))



Notes: (1) dotted lines denote proposed standards
(2) MPG = miles per gallon

MOBILE6 uses technology fractions to define the proportion of the fleet equipped with specific technology devices found to be significant in predicting in-use exhaust emission factors. The emission control technology mix in the US fleet would not be applicable to Jamaica, especially for model years that were in use before the phase out of leaded gasoline in 1996. The Jamaican fleet information database obtained from Inland Revenue includes vehicle make (manufacturer), model, model year and curb and gross vehicle weights (GVWR). Examination of the data revealed several issues:

- The majority of gross vehicle weight rating (GVWR) data (coded in the database as laden weights) was missing ;
- Most weights present were unladen (curb) weights but the same types of weights (i.e., laden or unladen) were reported in different units (e.g., pounds or hundred weight (cwt) and kilograms (kg));
- In some cases, and especially in the heavy duty vehicles classes, the fuel type (gasoline/diesel) and vehicle (e.g., tractor, trailer, motor car etc) were incorrectly assigned;
- In a few cases the vehicle type was incorrectly coded (e.g., some "Motor trucks" should have been" MOTOR TRACT" etc.

Considerable editing of the data was therefore required to insert GVWR (based on looking up manufacturers' information according to vehicle make and model). In such cases, the fuel type data were corrected as needed. For older vehicles, such data were not readily obtained and in those cases GVWRs were estimated based on the curb weights and expert judgment.

Considerable additional editing was required to correct the fuel type assignments for heavy duty vehicles. Statistics for the vehicle fleet composition (excluding trailers) between 2000 and 2005 are given in Tables 2.12 and 2.13.

Table 2.12: Breakdown of the Jamaican Vehicle Fleet in 2005

	VEHTYPE			Total
FUELTYPE	MOTOR CAR	MOTOR CYCLE	MOTOR TRUCK	
DIESEL	1967		20258	**22225**
PETROL	353124	26009	100627	**479760**
Total	**355091**	**26009**	**120885**	**501985**

Table 2.13: Breakdown of the Jamaican Vehicle Fleet in 2000

	VEHTYPE			Total
FUELTYPE	MOTOR CAR	MOTOR CYCLE	MOTOR TRUCK	
DIESEL	402		6,989	**7,391**
PETROL	269,603	20,272	84,510	**374,385**
Total	**270,005**	**20,272**	**91,499**	**381,776**

It should be noted that the fleet database (as of December 31, 2005) included vehicles that are typically classified as off-road vehicles – namely tractors, back hoes, bulldozers – and some of these are identified in the fleet data as Motor Tractors – presumably because they can spend some of the time on public roadways. These data, in addition to off-road vehicles used in the mining sector, were used to estimate emissions from off-road vehicles. The numbers of trailers listed in the database was excluded as such from the fleet data used in *MOBILE6* but in effect, the GVWR would and should include the weight of the trailer (and its maximum load).

The key input parameters used in *MOBILE 6* are indicated in Table 2.14. Those requiring Jamaica-specific values are highlighted and are discussed below.

Table 2.14: ***MOBILE6*** **Input Parameters**

Calendar year (2001 and 2006)*
Month (January, July)
Temperature
Altitude (high, low)
Weekend/weekday
Fuel characteristics (Reid vapour pressure (10 psi), sulphur content (1000 ppm for gasoline** and 5000 ppm for diesel, oxygenate content, etc.)
Humidity and solar load
Registration (age) distribution by vehicle class
Annual mileage accumulation by vehicle class
Diesel sales fractions by vehicle class and model year
Average speed distribution by hour and roadway
Distribution of vehicle miles travelled by roadway type
Engine starts per day by vehicle class and distribution by hour
Engine start soak time distribution by hour
Trip end distribution by hour
Average trip length distribution
Hot soak duration
Distribution of vehicle miles travelled by vehicle class
Full, partial, and multiple diurnal distribution by hour
Inspection and maintenance (I/M) program description
Anti-tampering inspection program description
Stage II refuelling emissions inspection program description
Natural gas vehicle fractions
Hydrocarbon species output
Particle size cut-off (10 µm)
Emission factors for PM and Hazardous air pollutants (HAPs)
Output format specifications and selections

*Assumed to be the same as December 2000 and December 2005
** Maximum allowed by model input. Actual specification for sulphur in gasoline is 1500 ppm (0.15%)
# Model defaults are indicated in italics; values used are underlined; and items requiring additional description (in text) are bolded

Registration (age) distribution by vehicle class and Diesel sales fractions by vehicle class and model year: The on-road fleet data base was used to generate the age (and vehicle class) distributions (Table 2.15). Retail fuels sales data were used to provide guidance on the overall fraction of diesel sales and the diesel fractions by vehicle class were estimated based on knowledge of the fleet.

Table 2.15: Annual Vehicle Registrations (2000-05)

REGYEAR	VEHTYPE					Total
	MOTOR CAR	MOTOR CYCLE	MOTOR TRACT	MOTOR TRUCK	TRAILER	
2000	16,543	960	58	6,183	212	23,956
2001	16,860	1,038	54	5,901	138	23,991
2002	19,191	1,093	58	7,026	102	27,470
2003	17,333	825	114	6,139	158	24,569
2004	16,552	1,235	71	5,320	385	23,563
2005	15,150	1,546	78	4,999	275	22,048
Total	**101,629**	**6,697**	**433**	**35,568**	**1,270**	**145,597**

* Note that the registrations in 2000 are already included in the fleet composition for 2000.

Annual mileage accumulation by vehicle class: A recent[12] survey of residential energy end users included estimates of distances travelled to work and school and these were used to provide one estimate of annual mileage accumulation for some vehicle classes. Table 2b of that report (reproduced in part in Table 2.15) included estimates of kilometres travelled in the past week of the survey for motor cars, SUVs, pickups and Minivans/Buses and motorcycles.

Table 2.16: Estimates of Weekly Distance Travelled in the Past Week* (2007)

	Motorcar	Pick-up	SUV	Mini-van/ Bus	Motorcycle
Mean km Travelled in past week	153	127	113	245	149
Prorated annual accumulation (km)	7,650	6,350	5,650	12,250	7,450
Prorated annual accumulation (miles)	4,754	3,946	3,511	7,612	4,629

* Based on data from Table 2b in (*PIOJ, STATIN, (2007). Residential Consumer End Use Survey: Volume 1 - Household Energy & Transport, Draft Report Prepared for: The Petroleum Corporation of Jamaica*)

These data represent a snapshot and the annual accumulation estimate based on the snapshot is likely on the low side based on the added contributions of the following:

- *Motor cars:* taxis and fleets (police vehicles, rental cars) which have far greater annual mileage accumulations.
- *Pickups and minibuses/vans*: use by commercial users and fare stage buses and taxis are a large fraction of the fleet in these vehicle classes and have considerably higher rates;
- *Motor cycles*: these data may be less subject to higher weighting since there are few fleets or users that have significantly higher accumulation rates.
- In the case of *urban buses*, Jamaica Urban Transit Company (JUTC) and Montego Bay Metro report their annual kilometres travelled and these data were used (together with the numbers of their operational fleet) to provide accurate data for the urban bus vehicle class.
- Data for *trucks* represent a challenge and few data are available on which to make estimates.

Average speed or speed distribution by hour and roadway: A single value rather than a distribution was used.

Distribution of vehicle miles travelled by roadway type (optional): This option was not used.

[12] 2005

Estimates of emissions were made for 2000 and 2005 and are presented in Tables 2.17 and 2.18 respectively for the vehicle classes used in the MOBILE6 model. The model outputs are emission factors for the vehicle categories that, when multiplied by the number of vehicles in each category, will give the emissions. Model results were used to estimate fuel consumption data and these were compared with MEMT fuel (gasoline and diesel) data for the transportation sector (Tables 2.17 and 2.18).

Table 2.17: Estimates of Motor Vehicle Emissions (2000)

	CO_2	CH_4	N_2O	NO_x	CO	NMVOCs	SO_2	Gasoline (bbl)	Diesel (bbl)
LDGV	987	0.056	0.084	4.42	91.8	11.2	0.90	2,570,010	-
LDGT12	273	0.015	0.023	0.96	25.7	2.58	0.25	711,790	-
LDGT34	51	0.003	0.004	0.17	5.03	0.49	0.05	132,948	-
LDGT	324	0.02	0.03	1.13	30.8	3.07	0.30	844,738	-
HDGV	376	0.021	0.032	2.87	36.4	1.60	0.35	978,492	-
LDDV	0.70	0.000	0.000	0.00	0.003	0.00	0.003	-	1,548
LDDT	25	0.001	0.001	0.06	0.061	0.03	0.12	-	54,052
HDDV	313	0.017	0.017	3.97	1.566	0.38	1.46	-	686,311
MC	26	0.001	0.002	0.14	3.53	1.04	0.02	67,621	-
Total	2,052	0.114	0.163	12.6	164	17.3	3.15	4,460,860	**741,911**
MEMT								4,164,441	1,101,232

Note: LDGT is the sum of LDGT12 and LDGT34

Table 2.18: Estimates of Motor Vehicle Emissions (2005)

	CO_2	CH_4	N_2O	NO_x	CO	NMVOCs	SO_2	gasoline	Diesel
LDGV	1,230	0.070	0.104	6.43	116.7	17.5	1.12	3,201,641	
LDGT12	328	0.019	0.028	2.47	49.6	8.22	0.30	853,203	
LDGT34	63	0.004	0.005	0.72	12.82	2.46	0.06	163,839	
LDGT#	391	0.02	0.03	3.18	62.4	10.68	0.36	1,017,042	
HDGV	456	0.026	0.039	3.17	95.7	11.11	0.42	1,186,307	
LDDV	4.03	0.000	0.000	0.02	0.017	0.01	0.019	0	8,856
LDDT	76	0.004	0.004	0.19	0.198	0.09	0.35	0	165,927
HDDV	450	0.025	0.025	3.87	1.734	0.25	2.10	0	989,038
MC	33	0.002	0.003	0.21	5.33	1.50	0.03	86,757	
Total	2,640	0.150	0.208	17.1	282	41.1	4.40	5,491,747	1,163,821
MEMT								4,729,988	1,172,699

Note: LDGT is the sum of LDGT12 and LDGT34

Comparing the fuel consumption estimates for 2000 and 2005, there is a large discrepancy between 2000 (~300k bbl or 33% for diesel and 360k bbl or 7% for gasoline) and 2005 (10k bbl or 0.1% for diesel and 760 k bbl or 16% for gasoline). These results warrant further analysis, even though in part they could be explained by the misclassification of the fuel type for a significant fraction of heavy duty vehicles and uncertain allocations of diesel fuel consumption to some categories.

<u>Railways (1A3c)</u>

Rail transportation in Jamaica is limited to the movement of bauxite and alumina. There is no passenger rail service. MEMT reports rail road fuel consumption data but there are several inconsistencies in terms of the fuels reported and the year to year variations. The reported fuels included gasoline, kerosene, asphalt and bunker C which are not attributable to rail transportation. Even in the case of diesel – the fuel used in rail engines – the MEMT data did not match bauxite alumina production data (since the bauxite/alumina sector is the only one that uses railways).

Data for bauxite and alumina production, rail shipments and rail-related fuel use were available from two companies. These data (fuel use per tonne-km) were used to estimate fuel use for the other two facilities. The rail (diesel) fuel use was taken into account when estimating the diesel fuel use for mining. That is, the fuel use for mining is the total fuel use less that for boilers and rail. Default emission factors from the 2006 IPCC Guidelines (for CO_2, CH_4 and N_2O) and the 1996 Revised IPCC Guidelines (for CO and NOx) were used to estimate rail GHG emissions (Table 2.19).

Table 2.19: Railway Emission Estimates (Gg) (2000-05)

Year	Emission (Gg)						
	CO2	CH4	N2O	NOx	CO	NMVOC	SO2
2000	24.3	0.0014	0.0094	0.39	0.33	0.065	0.046
2001	22.3	0.0012	0.0086	0.36	0.30	0.060	0.042
2002	27.2	0.0015	0.0105	0.44	0.37	0.074	0.052
2003	26.6	0.0015	0.0103	0.43	0.36	0.072	0.050
2004	26.8	0.0015	0.0103	0.43	0.36	0.072	0.051
2005	26.6	0.0015	0.0103	0.43	0.36	0.072	0.050

<u>Water-borne Navigation (1A3d) and Other Navigation (1A3e)</u>

These sub-sectors include emissions from fuels used to propel domestic and international water-borne vessels excluding fishing vessels (Category 1A3d), Fishing (1A4c) and other [primarily military] (1A5b) and off-road vehicles.

Waterborne vessels in category 1A3d are mainly recreational with limited movement of goods between Jamaican ports. Fuel deliveries to local end users and to international bunkers are tracked but some fuel use data for domestic vessels are likely included in retail fuel sales at service stations and to some commercial customers. The current data collection does not distinguish between agriculture, forestry and fishing end uses (Category 1A4c) but fuel use for this category is captured elsewhere (retail sales, government and “other” categories are compiled by MEMT). Because of this, no data are reported for this category.

The off-road category includes vehicles and mobile machinery used within mining (bulldozers, haul trucks), agriculture (agricultural tractors), industry (including construction and maintenance), forestry and residential sectors, and sectors such as airport ground support equipment. Engine types typically used in these off-road equipment include diesel and gasoline engines, 2-stroke engines, and motor gasoline 4-stroke engines. Most, if not all, of the off-road mobile equipment is included in the national motor vehicle data base and is identified as motor tractors. These include tractors, bulldozers, scrapers, back hoes etc. Fuel use for these vehicles is included in the reports for the bauxite and alumina and cement industries and in the case of construction and other sectors (other industry) the fuel use is included in the retail diesel and gasoline sales. Information on the vehicles used on the airside areas of airports for ground support equipment was not readily available. Fuel use for off road vehicles were not reported since fuels used for this category are also included elsewhere (bauxite mining vehicles, sugar and “Other”).

Table 2.20 provides the emissions for water-borne and other navigation.

Categories	CO_2	CH_4	N_2O	NO_x	CO	NMVOCs	SO_2
1A3 d Water-borne Navigation	64	0.0000	0.002	0.21	6.01	0.14	0.000
1A3 di International Water-borne Navigation (International Bunkers) (1)	64	0.0004	0.002	0.21	6.01	0.14	0.000
1A3 dii Domestic Water-borne Navigation	0.00	0.0000	0.000	0.00	0.00	-	0.000
1A3 e Other Transportation							
1A3 ei Pipeline Transport							
1A3 eii Off-road							

2.3.4 Fuel Combustion Activities – Other Sectors (1a4)

This sector includes emissions from combustion activities in commercial and institutional buildings (1A4a), residential buildings (1A4b) and emissions in agriculture, forestry and fishing industries (see Table 2.21). The emissions include those from fuel combustion for the generation of own-use electricity and heat.

Table 2.21: Emissions from Commercial/Institutional and Residential Sources (2000)

IPCC Category	CO_2	CH_4	N_2O	NOx	CO	NMVOCs	SO_2
	Gg						
1A4 Other Sectors	808	3.14	0.95	1.19	10.18	0.17	1.13
1A4 a Commercial/Institutional	677	0.01	0.00	0.14	0.01	0.00	1.08
1A4 b Residential	131	3.13	0.95	1.05	10.17	0.17	0.04

<u>Commercial and Institutional Buildings (1A4a)</u>

The sub-sector includes emissions from the following activities (ISIC Codes):

- Water supply (ISIC 41)
- Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods (ISIC 50-52)
- Hotels and restaurants (ISIC 55)
- Supporting and auxiliary transport activities; activities of travel agencies (ISIC 63)
- Post and telecommunications (ISIC 64)
- Financial intermediation (ISIC 65 – 67)
- Real estate, renting and business activities (ISIC 70 – 74)
- Public administration and defence; compulsory social security (ISIC 75)
- Education (ISIC 80)
- Health and social work (ISIC 85)
- Other community, social and personal service activities (ISIC 90 – 93)
- Extra-territorial organizations and bodies (ISIC 99).

Fuel use in this sector is limited to cooking since there is no heating of buildings. Fuel use data for government end users are routinely captured by MEMT. The fuels reported include gasoline, diesel, heavy fuel oil and lubricants. Liquefied petroleum gas (LPG) is allocated geographically (urban and rural), to a category called "Other" and "Other Manufacturing". These allocations do not permit reliable estimates of residential and commercial end users. The category "Other" was arbitrarily assumed to be commercial and institutional end users and urban and rural sales were assumed to be residential. The "Other Manufacturing" category was assigned to the manufacturing sector.

A recent survey of residential consumer energy end use did not include sufficient information to make more reliable estimates of residential LPG use. The gasoline and diesel fuel and lubricants use are assumed to be primarily for transportation with smaller amounts for own-use electricity generation. It was not feasible to estimate the split between these end uses and all of these fuels used were allocated to transportation. The reported use of Bunker C by the "Government" sector increased from 3,701 bbl in 2000 to 84,207 bbl in 2005 but the end use for Bunker C was not clear and the Bunker C values were retained in this sector.

Sales of LPG were assumed to be for cooking at various institutions. It is also possible that some commercial institutions obtained LPG from retailers. Emission factors for CO_2, CH_4 and N_2O from commercial and institutional sources were taken from the 2006 IPCC Guidelines.

Residential Buildings (1A4b)

Residential fuel use in Jamaica is limited to LPG for cooking and smaller amounts of kerosene. Wood and charcoal are also used for cooking. Emission factors (Tier 1) were taken from the 2006 IPCC Guidelines.

2.3.5 Fuel Combustion Activities - Non-Specified (1A5)

Sources in this category include stationary combustion sources not elsewhere listed and mobile emissions from military aviation and marine activities. Military fuel use data were available only for 2004 and 2005 and hence the average values for these years were assumed for 2000 to 2003. However, as noted above, since military aircraft were included in the LTO data for domestic flights and fuel use by JDF was included in the data from marketing companies, the emissions from these military activities are already included in the inventory. The data in Table 2.22 are provided only for information.

Table 2.22: Summary of Emissions for Non-Specified Sources (2000)

Categories	CO_2	CH_4	N_2O	NOx	CO	NMVOCs	SO_2
1A5 Non-Specified	*17.1*	*0.0*	*0.0*	*0.1*	*0.1*	*0.0*	*0.0*
1A5 a Stationary							
1A5 b Mobile	**17.1**	**0.000**	**0.000**	**0.060**	**0.110**	**0.013**	**0.000**
1A5 bi Mobile (aviation component)	6.54	0.000	0.000	0.023	0.009	0.005	0.000
1A5 bii Mobile (water-borne component)	8.77	0.000	0.000	0.031	0.012	0.006	0.000
1A5 biii Mobile (other)	1.75	0.000	0.000	0.006	0.089	0.003	0.000

2.3.6 Fugitive Emissions From Fuels – Oil And Natural Gas l (1B2)

Fugitive Emissions from Fuels – Oil and Natural Gas - Flaring (1B2b ii)

Emissions of CO_2, CH_4 and N_2O from flaring of natural gas and waste gas/vapour streams at oil facilities are included in sub-sector 1B2aii. The refinery[13] provided estimates of the amount of gases flared. Fugitive emissions of NMVOC (excluding venting and flaring) also arise from the petroleum refinery due to leaks at flanges and joints (sub sector 1B2aiii4) and from the transport and distribution of refined products (sub sector 1B2 aiii5), including those at bulk terminals and retail facilities. Evaporation losses from storage, filling and unloading activities and fugitive equipment leaks are the primary sources of these emissions. Emissions for these processes are summarized in Table 2.23.

[13] Petrojam

Table 2.23: Emissions from the Oil & Natural Gas Sector (2000)

IPCC Category	CO_2	CH_4	N_2O	NOx	CO	NMVOCs	SO_2
1B2 Oil and Natural Gas	4.21	0.00	0.00	0.00	0.00	2.05	0.89
1B2 a Oil	0						
1B2 ai Venting	0						
1B2 aii Flaring	4.21	0.00	0.00	0.00	0.00	0.00	0.00
1B2 aiii All Other	0						
1B2 aiii1 Exploration	0						
1B2 aiii2 Production and Upgrading	0						
1B2 aiii3 Transport	0						
1B2 aiii4 Refining	0.00	2.43E-08	0.00	0.00	0.00	0.59	0.89
1B2 aiii5 Distribution of Oil Products	0.00	0.00E+00	0.00	0.00	0.00	1.46	0.00
1B2 aiii6 Others							
1B2 b Natural Gas							
1B2 bi Venting							
1B2 bii Flaring							
1B2 biii All Other							
1B2 biii1 Exploration							
1B2 biii2 Production							
1B2 biii3 Processing							
1B2 biii4 Transmission and Storage							
1B2 biii5 Distribution							
1B2 biii6 Others							

Emission factors for CO_2 are determined by the carbon contents of fuels which, in general, are reliably known for liquid petroleum based fuels but are less accurate for solid fuels. The fuels of interest in Jamaica are motor and aviation gasoline, diesel and residual fuel oils, kerosene, and LPG. Smaller amounts of coal, bagasse and wood are used. The uncertainties in the CO_2 emission factors were based on the ranges provided for the default emission factors for stationary combustion given in the 2006 IPCC Guidelines.

Uncertainties for CH_4 and N_2O emission factors were taken as -70% to +230% -- also based on values given in the 2006 IPCC Guidelines.

Activity Values

National fuel consumption data are compiled by MEMT, while sectoral fuel data for the bauxite/alumina industry are compiled by JBI. In the former case (sales as well as import data), reports are filed by the refinery and petroleum marketing companies. The sectoral assignments by MEMT do not always match the traditional (i.e., ISIC) categories. For example, end use categories called "Other", "Government" and "Other Manufacturing" is reported but the data are not disaggregated into sectors corresponding to ISIC codes. Complete fuel uses for some activities (mining, rail transportation and lime manufacture) were not always available. For example, when mining operations are subcontracted by bauxite/alumina companies and the fuel use for all lime manufacturing plants were not included in data available from MEMT or JBI. It is also unclear if fuel use by the Jamaica Defence Force was included in "Government".

Because of these groupings, the required reports for some IPCC categories were either not reported separately (Food Processing, Beverages and Tobacco) or were likely incomplete (mining – which was reported in this inventory only for bauxite mining). On the other hand, fuel use data were available for the sugar industry and were reported separately. Some of the diesel fuel consumption by categories such as bauxite/alumina, sugar would have been used for transportation (i.e., on-road and off-road purposes) and it was not feasible to separate such use from fuel combustion. These allocations however constitute uncertainties not in the amounts used but rather in the allocation to sectors that are consistent with the IPCC sectors (which are aligned with ISIC categories). In the case of international aviation bunkers, the operation of flights between the two international airports as legs of international routes requires adjustment for the domestic component.

The on-road fleet database had significant gaps in vehicle weights as well as misallocations of type of fuel used by vehicles and vehicle type. Some, but not all, of these errors were corrected; additional editing of the database is required. It is also not clear how vehicles that are no longer in use are removed from the data base. There are also uncertainties in the annual vehicle kilometres travelled (except for JUTC buses), since odometer data are not captured nor have there been surveys dedicated to capturing such data. Information that should be available from fleet management operators and the Transport Authority should help to provide better estimates of the annual vehicle miles travelled. Estimates of these emissions will be more uncertain than if only fuel consumption data are used. Activity data (i.e., fuel consumption) for estimating the fuel use by domestic fishing and recreational boating as well as limited commercial (cargo) traffic between Jamaican ports are not available since some of the sales are recorded in other end-use categories.

2.4 Industrial Processes And Product Use (IPPU) GHG Emissions

This sector addresses GHG emissions that are released from industrial processes that chemically or physically transform materials and from the use of products which contain GHGs. Products such as refrigerators, foams or aerosol cans contain GHGs which can be released over time as the product is used and serviced. HFCs are used as alternatives to ozone depleting substances (ODS) in various types of product applications. Similarly, SF_6 and N_2O are used in a number of products used in industry.

The source categories covered in the Industrial Processes Sector and those that are present in Jamaica and therefore relevant for the inventory are summarized in Table 2.24. The sources that are present in Jamaica are indicated by a "Y" or "*". In the former case (Y), the inventory includes a specific worksheet to identify emissions while in the latter case (*) the emission estimates are included in another sector (because data were not available to disaggregate the emissions).

Table 2.24: Industrial Processes and Product Use Source Categories Present in Jamaica

Category Code	Category Name	Present In Jamaica#
2A	**MINERAL INDUSTRY**	
2A1	Cement Production	Y
2A2	Lime Production	Y
2A3	Glass Production	N
2A4	Other Process Uses of Carbonates	N
2A4a	Ceramics	N
2A4b	Other Uses of Soda Ash	N
2A4c	Non Metallurgical Magnesia Production	N
2A4d	Other	N
2A5	Other	N
2B	**Chemical Industry**	**N**
2B1	Ammonia Production	N
2B2	Nitric Acid Production	N
2B3	Adipic Acid Production	N
2B4	Caprolactam, Glyoxal and Glyoxylic Acid Production	N
2B5	Carbide Production	N
2B6	Titanium Dioxide Production	N
2B7	Soda Ash Production	N
2B8	Petrochemical and Carbon Black Production	N
2B8a	Methanol	N
2B8b	Ethylene	N
2B8c	Ethylene Dichloride and Vinyl Chloride Monomer	N
2B8d	Ethylene Oxide	N
2B8e	Acrylonitrile	N
2B8f	Carbon Black	N
2B9	Fluorochemical Production (Note 4)	N
2B9a	By-product Emissions (Note 5)	N
2B9b	Fugitive Emissions (Note 5)	N
2B10	Other - Sulphuric Acid	Y
2C	**Metal Industry**	
2D)	**Non-Energy Products from Fuels and Solvent Use**	
2D1	Lubricant Use	Y
2D2	Paraffin Wax Use	Y
2D3	Solvent Use (Note 8)	Y
2D4	Other (Note 9)	Y
2E	**Electronics Industry**	N
2F	**Product Uses as Substitutes for Ozone Depleting Substances**	
2F1	Refrigeration and Air Conditioning	Y
2F1a	Refrigeration and Stationary Air Conditioning	Y
2F1a	Mobile Air Conditioning	Y
2F2	Foam Blowing Agents	N
2F3	Fire Protection	Y
2F4	Aerosols	N
2F5	Solvents (Note 12)	N
2F6	Other Applications	N

Category Code	Category Name	Present In Jamaica#
2G	**Other Product Manufacture and Use**	
2G1	Electrical Equipment	N
2G2	SF6 and PFCs from Other Product Uses	N
2G3	N_2O from Product Uses	N
2G3a	Medical Applications	Y
2G3b	Propellant for Pressure and Aerosol Products	N
2G3c	Other	N
2G4	Other	N
2H	**Other**	
2H1	Pulp and Paper Industry (Note 15)	N
2H2	Food and Beverages Industry (Note 15)	*
2H3	Other	N

Y – Present in Jamaica

N – Not present

* Included elsewhere

2.4.1 Mineral Industry (2A)

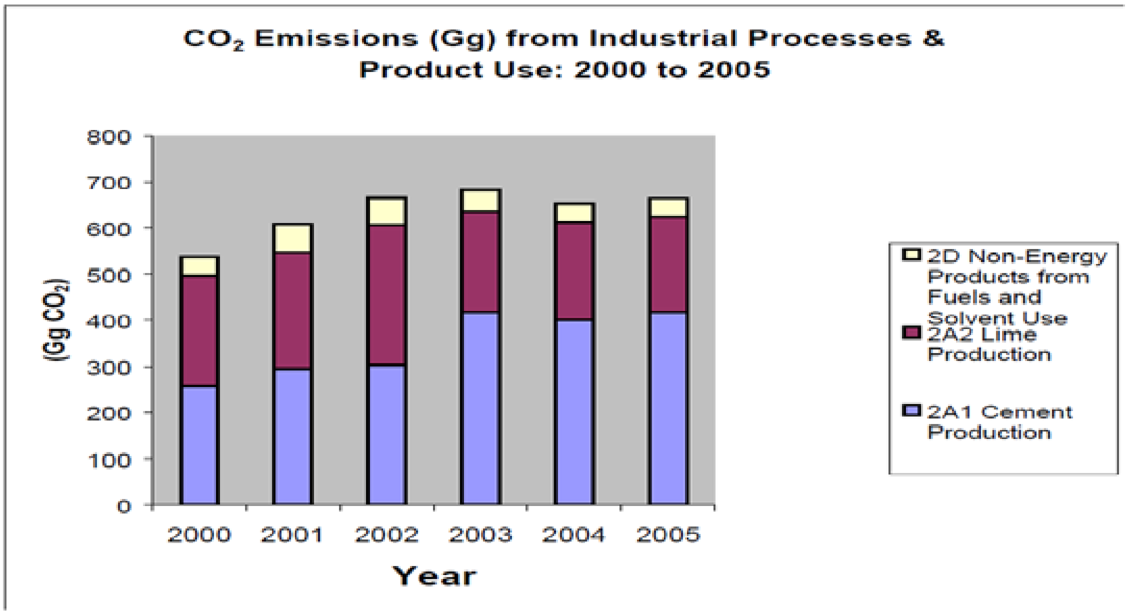
Cement and lime are produced in Jamaica by the calcinations of limestone. Cement is used in the construction industry while lime is used in the processing of bauxite into alumina and also in the sugar industry. Table 2.25 shows the summary of CO_2 emissions from cement and lime production (CO_2 is the only GHG released).

Table 2.25: CO_2 Emissions from the Mineral Industry (2000)

Category	CO_2 Emissions (Gg)
2A Mineral Industry	**497**
2A1 Cement Production	258
2A2 Lime Production	239

The emissions trends for 2000-05 for cement and lime production, as well as non-energy products from fuels and solvent use (i.e., lubricants, paraffin wax, solvents and asphalt production) are shown in Figure 2.15.

Figure 2.15: CO_2 emissions from the Industrial Processes and Product Use Sector (2000-05)



<u>Cement Production (2A1)</u>

The single cement plant in Jamaica produces lime form, high quality limestone and uses local shale and gypsum. Imports of cement (no clinker is imported) are used to supplement local needs. The Tier 1 method (equation 3.1) requires the cement production together with imports and exports of clinker.
The plant uses 0.2 tonne of gypsum for every tonne of clinker in the production of cement. Annual cement production (as well as cement import) data were provided by the company. There were no imports of clinker over the period 2000-05. The CO_2 emissions were estimated at 258 Gg in 2000 (Table 2.25).

<u>Lime Production (2A2)</u>

Lime is produced at kilns located at or near alumina refineries and at one other location. Annual lime production (as CaO) data were provided directly by four of the five lime manufacturing plants. The CO2 emissions from lime manufacturing were estimated at 239Gg in 2000 (Table 2.25).

2.4.2 Chemical Industry (2B)

The only facility qualifying as a chemical industry in Jamaica is a facility that makes sulphuric acid.

<u>Sulphuric Acid (2B10)</u>

Production data for sulphuric acid were obtained from the Economic and Social Survey Jamaica, 2005. The emission factor for SO_2 from sulphuric acid manufacture was assumed to be 13 kg/Mg product, assuming 98% conversion efficiency for SO_2 to SO_3. Emissions were negligible.

2.4.3 Non-Energy Products From Fuels And Solvent Use

The emissions from the use of lubricants, paraffin waxes, solvents, and the production of asphalt and use are included in this sub-sector. The resulting CO_2 and NMVOC emissions for 2000 are given in Table 2.26. The trend in CO_2 emissions for 2000-05 is shown in Figure 2.15 above.

Table 2.26: Emissions from Non-Energy Product Uses of Fuels and Other Chemical Products (2000)

	Emissions (Gg)	
Category	CO_2	NMVOCs
2D Non-Energy Products from Fuels and Solvent Use		
2D1 Lubricant Use	36.4	
2D2 Paraffin Wax Use	0.40	
2D3 Solvent Use(7) (Paints, Bitumen)		4.76

<u>Lubricant Use (2D1)</u>

Lubricants are mostly used in industrial and transportation applications. The associated emissions are therefore considered as non-combustion emissions and are included in the IPPU Sector. The emissions from lubricants used in 2-stroke engines, in which the lubricating oil is mixed with another fuel and both are intentionally burned, are reported in the energy sector.

The CO_2 emissions were estimated using the Tier 1 methodology since more detailed data on the amounts of each type of lubricant and the associated ODUs (oxidised during use) required for the Tier 2 method were not available. The default carbon content and ODU factor (0.2) were used. Lubricant consumption data (based on sales by petroleum marketing companies and Petrojam) are routinely captured and reported by MEMT. Estimates of CO_2 emissions from lubricant use in 2000 (36.4Gg) are included in Table 2.24.

<u>Paraffin Wax Use (2D2)</u>

Paraffin waxes are used in applications such as: candles, corrugated boxes, paper coating, board sizing, food production, wax polishes and surfactants (as used in detergents). CO_2 emissions from the use of waxes derive primarily when the waxes or derivatives of paraffin are burned during use (e.g., candles), and when they are incinerated with or without heat recovery or in wastewater treatment (for surfactants). In the cases of incineration and wastewater treatment, the emissions are reported in the Energy or Waste Sectors, respectively.

Paraffin wax and petroleum jelly import data were obtained from STATIN and the default values for the carbon content (20.0 kg/GJ) and ODU (0.2) were used to estimate CO_2 emissions using the Tier 1 methodology. A total of 0.4 Gg of CO2 emissions were estimated for 2000 (Table 2.24).

Asphalt Production and Use (2D4)

Emissions in this sub-sector include those from the use of bitumen in production of asphalt and its application in road paving and roofing operations. Emissions occur during the use of liquid asphalts as pavement sealant, in asphalt production in hot mix plants and subsequent releases from the road and roof surfaces. In the production of liquid asphalts (i.e., cutback asphalts), bitumen is mixed with a diluents (e.g., kerosene) – typically 24 to 35 percent by volume in the liquid asphalt. Nearly all (typically 95%) of the diluents is assumed to evaporate as NMVOC, since only rapid-cure cut back asphalts are used. Asphalt emulsions are also liquid but consist of an emulsion of bitumen with water (typically about 40% water). Cutback asphalts and asphalt emulsions are used for patching/repairing road surfaces and as a pre-coat in road construction.

The production of hot mix asphalt entails heating and mixing aggregate and bitumen in a hot mix plant or in a drum mixer near the road application site. The production and use of asphalt result mainly in emissions of NMVOC as well as CO, SO_2 and particulate matter. The remaining hydrocarbons remain stored in the product (much less than one per cent of the carbon is emitted).

The use of asphalt in roofing materials in Jamaica is assumed negligible relative to road construction uses and was therefore not disaggregated. Activity data to estimate emissions from asphalt emulsions were derived from the net consumption data. The amounts of cutback asphalt were estimated from (non-domestic) kerosene sales and assuming that the cutback contains 35 per cent kerosene.

Data were obtained from MEMT. All remaining bitumen was assumed to be used in hot mix asphalt plants. Emission factors of 242 kg NMVOC/tonne (88 lb NMVOC/bbl bitumen) and 25.3 kg NMVOC/tonne (9.2 lb/bbl asphalt) respectively for cutback asphalt and emulsified asphalt were used (Table 17.5.2 US EPA Emission Inventory Improvement Program, 2001. Volume III: Chapter 17 Asphalt Paving). Import, consumption and emissions data are given in Table 2.27.

Table 2.27: Net Production and Consumption and Emissions for Asphalt (2000-05)

Production# (bbl)	2000	2001	2002	2003	2004	2005
PEN ASPHALT 60/70	104,251	121,107	132,715	77,424	93,419	0
PEN ASPHALT 85/100	0	0	34,375	41,581	20,721	1,089
EMULSION ASPHALT	0	0	785	945	3,998	5,375
Net total ## (bbl)	104,251	121,107	167,875	119,950	118,138	6,464
Total Consumption ###(bbl)	99,455	120,759	183,560	203,009	254,753	129,413
Consumption Emulsion asphalt (bbl)	0	0	785	945	3,998	5375
Estimated Cutback (bbl)	30,371	36,877	23,783	70,111	89,654	60,886
Estimated Hot mix (bbl)	69,084	83,882	159,777	132,898	165,099	68,527
NMVOC Emissions (Gg)						
Cutback	1.21	1.47	0.95	2.80	3.58	2.43
Emulsion	0.0000	0.0000	0.0033	0.0039	0.0167	0.0224
Total NMVOC Emissions (Gg)	**1.21**	**1.47**	**0.953**	**2.80**	**3.60**	**2.45**

Petrojam data
Net also takes imports into account
MEMT data

2.4.4 Product Uses As Substitutes For Ozone Depleting Substances (2F)

The fluorinated replacement chemicals for ozone depleting substances (ODSs) of interest are HFCs and PFCs because they have high global warming potentials (GWPs) and they are not reported under the Montreal Protocol. [Substances reported under the Montreal Protocol include CFCs, Halons, Other Fully Halogenated CFCs, Carbon Tetrachloride, Methyl Chloroform, HCFCs, HBFCs, Bromochloromethane and Methyl Bromide.] HFCs and PFCs are found in various applications such as:

- Refrigeration and Air Conditioning
- Mobile Air Conditioning
- Foam Blowing Agents
- Fire Protection
- Aerosols
- Solvents

These applications utilise a range of chemicals (HFCs, CFCs and HCFCs) and have a wide range of emission characteristics. For example, HFCs and PFCs in rigid foam (typically closed-cell foam), refrigeration and fire suppression equipment can lead to long-lived banks of material. Other applications, such as aerosols, solvents and solvent cleaning may have short-term inventories of stock but can be considered as sources of prompt emissions. This also applies to flexible foams (typically open-cell foams).

There are no known uses of SF_6 in Jamaica and neither was there any information for HFCs in aerosol products and foam products in Jamaica so these applications were ignored. Refrigerators and freezers manufactured before 2005 were insulated with foam that contain either CFCs or HCFCs, but since 2005 HFCs have been used in foam blowing agents in refrigerators and freezers. Consequently, HFC emissions from foam products were ignored also.

Some fire suppression systems in Jamaica use HFCs (HFC-227ea) and there is limited use of HFCs (HFC-245fa) as a solvent. Table 2.28 summarizes the HFCs and PFCs used in various applications together with an indication of the HFCs that are known to be present in applications used in Jamaica. Estimates of HFCs were made for refrigeration, air conditioning, mobile air conditioning, fire suppression and solvent applications.

Table 2.28: Main Application Areas for HFCs and PFCs and their GWP and Indication of HFCs Imported into Jamaica (shaded)

Chemical	Typical Trade name(s) or blends with agent#	ASHRAE NAME	GWP *	Refrigeration & Air Conditioning	Fire Suppression & Explosion Protection	Aerosols		Solvent Cleaning	*Foam Blowing*
						Propellant	Solvent		
HFC-23		R23	1170	X	X				
HFC-32		R32	650	X					
HFC-125	R-404a, R410a, R-507	R125	2800	X	X				
HFC-134a	Floron 134a, Forane 134a, Formacel Z4, Genetron 134a, ISCEON 134a, Klea 134a, Meforex 134a, Solkane 134a (F), Solkane 134a (R), Suva 134a, R-404a, R-407c	R134	1300	X	X	X			*X*
HFC-143a	R-404a, R-408a, R-507	R152	3800	X					
HFC-152a	R-401b	R227a	140	X		X			*X*
HFC-227ea	FM-200 Heptafluoropropylene	R227	2900	X	X	X			*X*
HFC-236fe			6300	X	X				
HFC-125/HFC-143a/HFC-134a (44%/52%/4%)	Klea 404A, EcoloAce 404a	R404a							
R-22/R-125, R143a (7%/46%/47%)	Suva 408	R408a							
R22/R-124, R-142b (25%/15%/60%)		R409a							
HFC-125/HFC-32 (50/50)		R410							
R124, R143a (50%/50%)	Suva 507, Asahiklin SA-28, AZ50, ISCEON 507, Forane 507, Meforex 57, Klea 507	R507							
HFC-245fa	FC-129			X		X	X		*X*
HFC-245fe							X		*X*
HFC-365mfc							X	X	*X*
HFC-43-10mee			1300				X	X	
PFC-14		R14			X				
PFC-116		R116							
PFC-218		R218							
PFC-31-10					X				
PFC-51-14								*X*	

* - IPPC 1996 Guidelines (100 year time horizon)

Trade names are listed only when the ODS material is used in Jamaica – indicated by shaded cells (use grey instead of yellow)

Refrigeration and Air Conditioning (2F1)

Jamaica began phasing out the use of CFCs in refrigeration and air-conditioning (RAC) systems in 1998; replacing them with Freon 22 and, more recently, with HFCs and blends containing HFCs. Import restrictions for CFCs based on a declining quota system were put in place in 1999 and importation of CFCs ceased in December 2005. CFC imports to Jamaica decreased from 210.4 tonnes in 1999 to 5 tonnes in 2005. HCFC imports decreased from 11.3 t in 2001 to 0.7 t in 2006. The refrigerant R22 is used mainly in air conditioning systems while HFC-134a is used almost exclusively in mobile air conditioning systems and also in some types of refrigeration applications.

Since there is no production, export or destruction of virgin HFCs and PFCs in Jamaica, emissions were therefore calculated using the Tier 1a method in the 2006 Revised Guidelines. The Tier 1a method is based on application level (as opposed to equipment level) data. This required annual chemical consumption data derived from imports of bulk (cylinders) chemicals in products/applications (refrigerators, stationary and mobile air conditioners etc.). The latter reflect the amounts in banks.

Import data were obtained from STATIN for 2000-05. Emission estimates for each year were made using the following assumptions:

- Percent default emission factor applied to bank inventory annually; and
- First year of introduction of each chemical used as bank inventory year.

Imports of refrigeration and air conditioning equipment are indicated in Tables 2.29 and 2.30 and an equipment profile for Jamaica in 2002 is given in Table 2.31.

Table 2.29: Bulk imports of HFCs (2000-05)

	IMPORTS (KG)										
YEAR	HFC-23	HFC-32	HFC-125	HFC-134a	HFC-143a	HFC-152a	HFC-227ea	HFC-236fa	HFC-245fa	HFC-365mfc	HFC-43-10mee
2000		0.0	1,144.0	2,935.6	1,352.0	18.1	0.0	0.0	0.0	0.0	0.0
2001		0.0	1,645.3	34,980.0	1,945.7	0.0	0.0	0.0	640.8	0.0	0.0
2002		0.0	3,430.9	48,426.8	7,526.4	0.0	0.0	0.0	0.0	0.0	0.0
2003		28.8	3,624.6	51,206.7	4,018.7	0.0	6,308.20.0	0.0	25.4	0.0	0.0
2004		1,036.1	16,065.0	41,318.5	2,326.1	0.0	0.0	0.0	0.0	0.0	0.0
2005		868.5	7,041.1	69,253.8	10,521.2	0.0	0.0	0.0	0.0	0.0	0.0

Table 2.30: Imports of Refrigeration and Air-Conditioning Equipment (2000-06)

EQUIPMENT TYPE	2000	2001	2002	2003	2004	2005
Domestic Refrigeration	53,659	45,627	54,935	52,568	58,394	60,588

Stand-alone Commercial Applications	**NA**	NA	**5,296**	**3,980**	**3,610**	**4,702**
Medium & Large Commercial Refrigeration	**517**	**297**	**347**	**525**	**1,733**	**1,171**
Residential & Commercial A/C including Heat Pumps	**3,219**	**4,488**	**5,513**	**6,750**	**10,007**	**20,035**
Mobile A/C	**22,270**	**23,175**	**25,825**	**30,131**	**22,114**	**16,449**

Table 2.31: Equipment Profile for Jamaica (2002)

EQUIPMENT TYPE	UNITS	CHARGE (KG)	CFC POPULATION
Small A/C units	176,000	1.5	80,000
Medium sized A/C units	840	75	500
Large A/C units	90	200	12
Mobile A/C	233,000*	104	
Chillers	30	200-600	
Home Refrigerators	560,00	0.4	60%
A/C units and chillers were in 3196 establishments. *The estimate was based on the number of Certificates of Fitness issues			

Import data for bulk HFC chemicals by chemical compound (Table 2.28) were obtained from the Statistical Institute of Jamaica (STATIN). The individual HFCs were calculated from the pure HFC products and the percentages of HFCs in blends. Some shipments consisted of a number of different cylinders that were not always completely itemized by product. In such cases the total weight of the shipment was allocated evenly among those products listed - taking into consideration different cylinder weights that were provided. The import data did not allow the identification of the end use in cases where the HFC has more than one application (especially R-134a which is used in refrigeration as well as in mobile air conditioning).

Household refrigerators and window air conditioning units (see Table 2.29) are readily identified in the import data, but data for medium sized and larger systems in industrial, commercial and institutional establishments, the type and size of the units were not always clearly identifiable.

The numbers of vehicles imported each year were obtained from STATIN, Ministry of Transport and Works Annual Transport Statistics Report: Jamaica in Figures 2003-2004 (2005) and 2004-2005 (2006) and the Ministry of Transport and Works Draft National Transport Policy (2007) in order to estimate the number of mobile air conditioning units. There are some refrigerated vehicles but their number is not known.

All household refrigerators and mobile air conditioning equipment imported between 2000 and 2005 was assumed to be charged with HFC-134a. It was also assumed that all motor cars, trucks and tractors (but not trailers) imported during 2000-05 were equipped with air conditioners. The charges in the household refrigerators and mobile air conditioners given in Table 2.31 were used to estimate the amounts of HFCs (R134a) in this imported equipment.

For small air conditioners (window & wall units) the vast majority imported over the same period will have HCFC Freon (R-22) with smaller numbers of units with refrigerants such as R410a.

In the case of the medium sized and larger systems in commercial and industrial establishments (e.g., refrigerator/freezer chests/cabinets/showcases, air conditioners with reverse cycle refrigeration, chillers, etc.) it was not feasible to determine precisely the sizes of systems and the types of refrigerants charged in the imported systems. Since there were bulk chemical imports of R227 and HFC blends (R-404a, R-410a, R-408a) it is evident that these were used to service existing equipment. Because of this, the use of Tier 2 methods was not feasible and so the Tier 1 method in the 2006 IPCC Guidelines was used. The default values for the assumed equipment lifetime (15 years) and emission factor from the installed base (15%) and the % destroyed at end of life (0%) were used. Table 2.32 shows the annual emissions of the HFCs from refrigeration and air conditioning.

Table 2.32: Annual HFC Emissions from Refrigeration and Air Conditioning (2000-05)

COMPOUND	EMISSIONS (TONNE)					
	2000	2001	2002	2003	2004	2005
HFCs/PFCs	0.0	0.0	0.0	0.0	0.0	0.0
HFC-23	0.0	0.0	0.0	0.0	0.2	0.3
HFC-32	0.3	0.4	1.3	2.0	2.0	2.8
HFC-125	0.9	30.1	43.9	54.6	63.0	75.6
HFC-134a	0.4	0.6	2.2	2.8	2.7	3.9
HFC-143a	0.0	0.0	0.0	0.0	0.0	0.0
HFC-152a	0.0	0.0	0.0	0.9	0.8	0.7
HFC-236fa	0.0	0.0	0.0	0.0	0.0	0.0

Fire Protection (2F3)

Examination of the import data indicated that the only HFC imported for fire suppression during 2000-05 was HFC-227e (trade name FM200). Fire suppression systems using FM200 are typically used in computer and telecommunication rooms. Imports of FM200 occurred only in 2003, even though applications using FM 200 in Jamaica have been in use for some time. There were insufficient data to make reliable estimates of emissions.

Aerosols (Propellants and Solvents) (2F4)

Most aerosol packages contain hydrocarbon (HC) as propellants but HFCs and PFCs may also be used as propellants or solvents in a small fraction of the total. Emissions from aerosols usually occur shortly after production, on average six months after sale.

The five main sub-applications are as follows:

- Metered Dose Inhalers (MDIs);
- Personal Care Products (e.g., hair care, deodorant, shaving cream);
- Household Products (e.g., air-fresheners, oven and fabric cleaners);
- Industrial Products (e.g., special cleaning sprays such as those for operating electrical contact, lubricants, pipe-freezers);
- Other General Products (e.g., silly string, tyre inflators, klaxons).

The HFCs currently used as propellants are HFC-134a, HFC-227ea, and HFC-152a. The substances HFC-245fa, HFC-365mfc, HFC-43-10mee and a PFC, perfluorohexane, are used as solvents in industrial aerosol products. Of these, HFC-43-10mee is the most widely used. 11 HFC-365mfc is also expected to be used within aerosols in the near future.

Data for the region that includes Jamaica (Rest of Latin America which includes Caribbean countries) as reported by the USEPA indicated that HFC emissions due to aerosol use in 2005 were estimated at 0.10 tonne carbon dioxide eq. for MDIs and nil for non-MDI applications. On this basis the emissions in Jamaica were assumed to be negligible.

There is limited use of HFCs as a solvent and the only application identified was the use of HFC-245fa (trade name FC-129) which is used as a surfactant in some paints. Small quantities (a total of 666 kg) were imported in 2001 and 2003.

It was assumed that the quantity imported was used over current and the following two years that all amounts used were emitted in the year of use and that the amount imported in 1999 was the same as that in 2001. The emissions for HFC-245fa are summarized in Table 2.33.

Table 2.33: Annual Emissions for HFCs used as Solvents (2000-05)

YEAR	IMPORTS (TONNE)	EMISSIONS (GG)
2000	**0**	**0.0002**
2001	**0.6408**	**0.0004**
2002	**0**	**0.0002**
2003	**0.0254**	**0.0002**
2004	**0**	**0.0000**
2005	**0**	**0.0000**

Medical Applications

N_2O emissions arise from various types of product use, including:

- Medical applications (anaesthetic use, analgesic use and veterinary use);
- Use as a propellant in aerosol products, primarily in food industry (pressure-packaged whipped cream, etc);
- Oxidizing agent and etchant used in semiconductor manufacturing;
- Oxidizing agent used, with acetylene, in atomic absorption spectrometry;
- Production of sodium azide, which is used to inflate airbags;
- Fuel oxidant in auto racing; and
- Oxidizing agent in blowtorches used by jewellers and others.

Medical applications are the only known applications in Jamaica and all imports were assumed to be as such. Medical applications will result in all of the N_2O being emitted. Import data were available for 2000-04 (see Table 2.34) and hence data for 2005 were assumed to be the same as for 2004.

Table 2.34: Nitrous Oxide Imports and Emissions (2000-04)

YEAR	2000	2001	2002	2003	2004	2005
Import (kg)	52,036.0	78,177.0	87,212.0	62,340.0	73,037.0	NA
Emissions	52.0	65.1	82.7	74.8	67.7	73.0

(tonne)						

2.4.5 Other (2H)

The use of some solvents and certain consumer products are significant sources of emissions of NMVOCs. The 2006 IPCC Guidelines did not include a section on estimates of emissions from solvent use. Examples of the solvents and products that release NMVOCs and are relevant for Jamaica are given in Table 2.35. The sources that are present in Jamaica are indicated by a "Y" or "*". In the former case (Y), the inventory includes a specific worksheet to identify emissions while in the latter case (*) the emission estimates are included in another sector (because data were not available to disaggregate the emissions).

Table 2.35: Source Categories for NMVOC Emissions Present in Jamaica

Sub-category	Description of Solvent	Relevant to Jamaica
Surface coating (e.g. painting) operations	Applications of paints, lacquer, enamel and primer to cans, wood products, metal parts, buildings, etc. Use of thinning solvents.	Y
Paper coating operations	Coating operations, mixing, and use of thinning solvents.	N
Printing and publishing	Press operations, lithography, and use of thinning solvents.	*
General solvent use	Vapour degreasing, dry cleaning, textile manufacture, personal care & household products use.	Y
Production of trucks and automobiles	Surface coating, cleaning/degreasing operations.	N
Ship building	Surface coating, cleaning/degreasing operations.	N
Chemical products manufacture and processing	Solvents are used in a variety of applications in the manufacturing of chemicals and chemical products. Textile fabric printing, manufacture of rubber products, polyester resin plastic products manufacture, tank and drum cleaning, waste solvent reclamation, solvent degreasing.	N
Graphic arts	General graphical printing, publication gravure printing.	*

Commercial and consumer use of various products release VOCs when the product is used (e.g., painting) and VOCs evaporate, or when there is direct release into the atmosphere (e.g., aerosol sprays). Commercial and consumer products that release VOCs include aerosols, household products, toiletries, rubbing compounds, windshield washing fluids, polishes and waxes, non-industrial adhesives, space deodorants, moth control applications, and laundry detergents and treatments.

Food and Beverages Industry

Emissions of NMVOC occur in the manufacture of alcoholic beverages (rum and beer) and from food production (primarily bread and cakes; margarine and solid cooking fats). Production data for the products except bread were obtained from Economic and Social Survey of Jamaica (ESSJ) reports. Data for bread and baked products were estimated from FAO per capita consumption for wheat & wheat products (FAOSTAT www.fao.org/faostat/foodsecurity/index_en.htm) and population data.

Emission factors (kg NMVOC/tonne food) were obtained from the 1996 Revised IPCC Guidelines for Meat, Fish and Poultry, Coffee roasting, Margarine & solid cooking fats, Bread (Wheat & Wheat products), Sugar and Animal Feed. The NMVOC emissions are given in Table 2.36.

Table 2.36: NMVOC Emissions from the Food and Beverage Industry (2000-05)

Product	Emission Factor (kg NMVOC/ tonne produced)	NMVOC Emissions (Gg)					
		2000	2001	2002	2003	2004	2005
Meat, Fish and Poultry	0.3	0.023	0.025	0.025	0.028	0.025	0.031
Coffee roasting	0.55	0.018	0.015	0.022	0.016	0.018	0.010
Margarine & solid cooking fats	10	0.062	0.068	0.067	0.068	0.074	0.070
Bread (wheat & wheat products)	8	1.703	1.681	1.958	2.210	2.473	2.789
Sugar	10	0.833	0.705	0.662	0.663	0.981	0.768
Animal Food	1	NA	NA	NA	NA	NA	NA
Total		2.64	2.49	2.73	2.98	3.58	3.67

Paints

Estimates for emissions from paints were based on the local production data plus imports minus exports. Emissions from paints depend on the solvent content of paint, which may vary even within the same type of paint. The estimates are made by multiplying the sales data (mass of paint) for each type of paint by an average solvent content for each type of paint (see Table 2.37).

Table 2.37: Typical Solvent Content for Paints

Category	Mean solvent content (%)
Waterborne paint	< 20
Powder paint	0
High-solid paint (1 pack alkyds)	< 30
Low-solvent (1 pack radiation cure)a	0 - 3
Low-solvent (2 pack epoxy)b	< 10
Low-solvent (2 pack polyurethane paint)b	< 10
Conventional solvent paint	40 - 70

Source: ECE - VOC Task Force, 1990

CORINAIR Group_06 Solvent and Other Product Use page B610-9

The net paint trade data were obtained from the UN Statistics Division Commodity Trade Database while local production data (Table 2.38) were obtained from the ESSJ 2005.

Table 2.38: Local Paint Production Data (2000-05)

Year	Production ('000 litres)						VOC (g/L)
	2000	2001	2002	2003	2004	2005	
Total	9,624	9,363	10,337	11,216	11,283	12,073	
Water based (60%)	5,774	5,618	6,202	6,730	6,770	7,244	380
Solvent based (40%)	3,850	3,745	4,135	4,486	4,513	4,829	600

Solvent and water based paint production or paint plant capacity data for 2003 obtained from National Environment and Planning Agency (NEPA) indicated that the split between solvent and water based paints was approximately 60% for water based and 40% for solvent based paints and the same split was assumed for the other years. The NMVOC content for imported paints were assumed to meet the US

National limits for non-flat interior and exterior coatings (380 g/L) and varnishes (600 g/L); these limits were used respectively for the water based and solvent based paints produced locally.

The local paints were assumed to meet the Jamaica Bureau of Standards specifications which have limits for the percentage of volatile matter [including water) of 55% for flat emulsion (interior and exterior low sheen and semi-gloss) and 35% oil modified alkyd interior and exterior paints. In the absence of VOC content from local paint manufacturers, the VOC contents from the UN Statistics Division Commodity Trade Database (380 g/L for water based and 600 g/l for solvent based paints) were used to estimate NMVOC emissions. It was also assumed that all paints produced were used in the year of production. NMVOC emission estimates are given in Table 2.39.

Table 2.39: NMVOC Emissions from Paints (2000-05)

Type of Paint	Emissions (Gg)					
	2000	20021	2002	2003	2004	2005
Water based (60%)	2.19	2.13	2.36	2.56	2.57	2.75
Solvent based (40%)	2.31	2.25	2.48	2.69	2.71	2.90
Polymer based paints, varnishes in non-aqueous medium	0.11	0.21	0.26	0.20	0.27	0.61
Polymer based paints, varnishes in aqueous medium	0.06	0.05	0.09	0.12	0.25	0.14
Paints and varnishes nes, water pigments for leather	0.02	0.07	0.07	0.04	-0.01	0.00
Organic composite solvents, paint, varnish remover etc	0.06	0.06	0.12	0.15	0.10	0.37
Total	4.76	4.77	5.38	5.76	5.88	6.77

<u>Personal Care Products</u>

Emissions for commercial/consumer solvent use (except paints) are based on multiplying the population data by the per capita emission factors for consumer and commercial solvent use. No specific guidance is provided in the 2006 IPCC Guideline on default emission factors for personal care products. Emission factors for commercial and consumer solvent use available from US or European sources were used in the absence of other data. Table 2.40 identifies per capita emission factors published by the US EPA for Commercial/Consumer Solvent Usage. Emissions estimates are given in Table 2.41.

Table 2.40: Evaporative Emissions from Commercial/Consumer Solvent Use

Use	Per Capita Emission Factors kg/person/y
Personal Care Products	1.05
Household products	0.36
Automotive Aftermarket Products	0.62
Adhesives and Sealants	0.26
FIFRA-Regulated Products (Pesticides)	0.81
Coatings and Related Products	0.43
Miscellaneous Products	0.03
Total	3.56

Table 2.41: Evaporative Emissions from Commercial/Consumer Solvent Use (2000-05)

	2000	2001	2002	2003	2004	2005
Category	Emissions (Gg)					
Consumer products	10.9	10.9	11.0	11.0	11.1	11.1

2.4.6 Uncertainties, Quality Assurance And Control

Cement: Plant-specific cement production and historical fraction of clinker in cement were available and were considered to have an uncertainty of (5%) near the middle of the typical uncertainty range (2-7%) for the fraction of CaO in clinker. The uncertainty in the emission factor was assumed negligible since it depends on the stoichiometry for the release of CO_2 from limestone.

Lime: Plant-specific data were obtained for three of four lime plants but only one plant provided lime (CaO) content data. Because of this, the uncertainty in activity data is estimated as 4%. The emission factor is based on stoichiometry and the uncertainty in the emission factor is determined by that in the composition of lime. Only one of the four plants provided data based on chemical analysis and hence the uncertainty is estimated to be 8% – at the high end of the typical range (4-8%). Lime production data were compared with lime use in the alumina and sugar industries and were found to be consistent.

Sulphuric acid: Production data were obtained from national statistical data (in the absence of plant-specific data) which were rounded to the nearest thousand tonnes. The estimated uncertainty in the activity (production) data is 10%. The emission factor used (CORINAIR SNAP 040401) had a range of 10 to 25 kg/Mg or 41%.

HFCs: The data in Table 2.30 regarding imports of RAC equipment were based on the number of Certificates of Fitness issued and nearly all motor vehicles (excluding motor cycles) were assumed to have air conditioning; 60% of which were assumed to contain CFCs. The imports may be compared with the estimates for the populations of the various equipment types for 2002 (UNDP, 2002. United Nations Development Programme, Project of the Government of Jamaica, Project Document). CFCs were the refrigerant of choice up to 1993 when HFC-134a or R-401C was introduced. It has been assumed that 60% of vehicles globally were equipped with HFC-134a in 1995 (Baker, J.A. (1998). Mobile Air Conditioning: HFC-134a Emissions and Emission Reduction Strategies. UNEP TEAP HFC/PFC Task Force). Estimates of potential HFC emissions were made in order to serve as a quality control (QC) check on the Tier 1 method.

Lubricant and Paraffin Wax Use: The default uncertainties in the ODU factors (50%) were used for the uncertainty in emission factors. The reporting of lubricant consumption appeared to be given lower priority and an uncertainty of ±20% was assumed. The activity data for paraffin wax were based on import data. The end use of paraffin wax is uncertain since CO_2 emissions occur only in the case of candles or when products containing paraffin waxes are burned. Import data did not always allow identification of candle use and some wax coated products are placed in landfills instead of burned. An uncertainty estimate of ±50% was assumed in the case of the activity data for paraffin wax

Solvent Use Paints: Paint production data are reported to PIOJ but the reported production data are not broken down by type of paint. There are three local standards for paints but they do not include specifications for the VOC content based on the paint application – unlike standards for paints in Europe and North America. Uncertainties in total production are considered to be about 10% (because of the rounding). The split between solvent and water based paints was assumed to be the same for all years based on data reported for one year. The uncertainties are estimated to be 30% for activity (production data) and 30%for emission factors.

Asphalt/Bitumen: The emission factors for NMVOC emulsion and cutback asphalt use will be about ±100 percent uncertain (i.e., between -50 percent and +100 percent). The consumption data were estimated from kerosene data and the uncertainties are estimated to be ±50% because of difficulties in assigning end use for fuels.

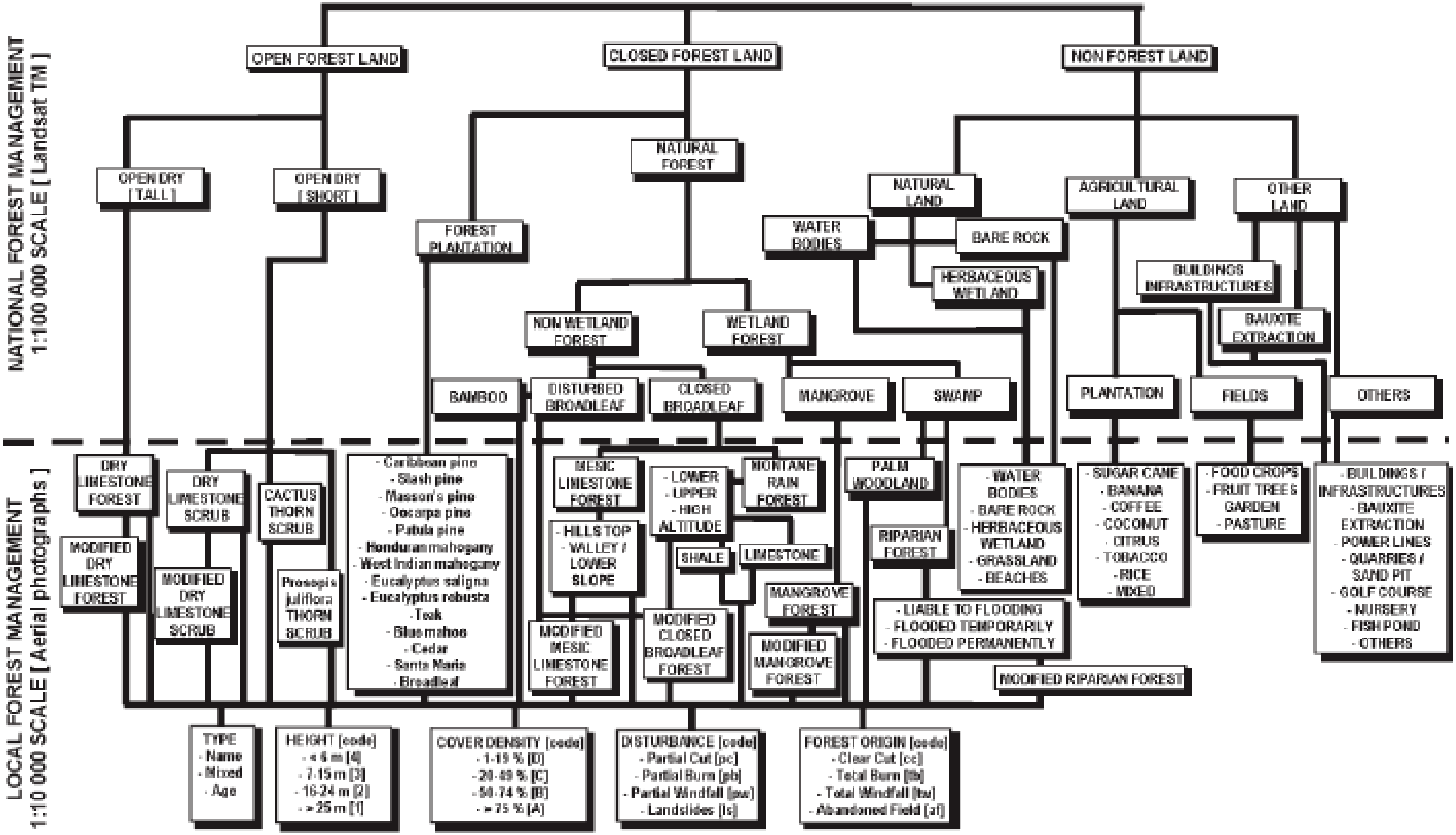
Personal care products: Estimates are based on population data and per capita use for personal care products derived from US data. The former is considered to have an uncertainty of 2% but the use of US data and the dependence of product use on factors such as lifestyle, income, climate, etc., make estimates of the uncertainty challenging. An uncertainty of ±200% for the emission factor was arbitrarily assumed.

2.5 AGRICULTURE, FORESTRY AND OTHER LAND USE SECTOR GHG EMISSIONS AND SINKS

2.5.1 Forestry

This section addresses Jamaica's GHG inventory estimates for the forestry and land use sector for the years 2000-05. It was prepared using on *2006 IPCC Guidelines*. Fairly good country specific data are available for the forests and land use sectors in Jamaica. A systematic data gathering process started in 2000 after a critical analysis of the existing land use/cover and land classification systems was completed by the Forestry Department (Camirand and Evelyn, 2003). This analysis determined that no system had the characteristics or capability for classifying Jamaican forests for forest management, conservation, or the evaluation for forest development. A standardized broad classification system was 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, 2001).

Figure 2.16: Diagram of Land Use/Cover Types Hierarchical Classification in Jamaica[14]



[14] Source Evelyn and Camirand (2003)

The process is a hierarchical system, as shown in Figure 2.16. Evelyn and Camirand (2003) also used this classification system for reporting, among other things, details of deforestation and land use/cover changes in Jamaica from 1989-98. They reported that the 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.

The *2006 IPCC Guidelines* require reporting on six land-use categories.
These categories are not dissimilar to Jamaica's national 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 (Forest Department, 2001). The classes were then aggregated to 11 categories (see Table 4 in Camirand and Evelyn, 2004). At the national level, these categories were further divided into three broad categories: Forest, Mixed and Non-Forest. This classification is shown in Table 2.42 together with how they relate to the *GHG Inventory* classes.

Table 2.42: National Land Use/Cover Classes and Equivalent GHG Categories[15]

Code	Jamaica National Land Use classes	Definitions	GHG Inventory Land Use Categories
Forests (1)			
PF	Closed broadleaf	Closed primary forest with broadleaf trees at least 5 m tall and crown interlocking, with minimal human disturbance	Forest Land
SF	Disturbed broadleaf	Disturbed broadleaf forest with trees at least 5 m tall and species-indicators of disturbance such as *Ceropia peltata* (trumpet tree)	Forest Land
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
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* (cashaw) or *Stenocereus hystrix* (columnar cactus)	Forest Land
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
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
PP	Carib Pine Plantation	Forest plantation with Pinus caribaea	Forest Land
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
Mixed			
SC	Disturbed Broadleaf Forest & Non-Forest land Use	>50% Disturbed Broadleaf forest; >25% Non-Forest Land Use (2)	75% Forest Land 25% Otherland
CS	Non-Forest land Use &	>50% Non-Forest Land Use (2);	75%: 76% Otherland, 24% Grassland
	Disturbed Broadleaf Forest	>25% Disturbed Broadleaf forest	25% Forest Land
Non-Forest (3)			
	Non-Forest land use	Non-Forest land use	20% Cropland, 64% Grassland, 3% Wetlands, 12% Settlements, 1% Otherland

(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.

15 Modified and extended from Camirand and Evelyn, (2004)

The area of forested lands estimated for 2005 after reclassification and calibration for the FAO Global Forest Resource Assessment 2005 Country Report (FRA, 2005) was 341,000 ha (30%) of the island's surface area. Most of this land could be classified as managed forest following the 2006 IPCC Guidelines definitions. This is because anthropogenic activities, such as extraction of wood and non-wood forest products, are taking place in almost all the forests of Jamaica. About 114,300 ha of this area has been designated as Forest Reserves and other protected areas, and therefore is under continuous management as stipulated by the Forest Act, 1996 (Section 8 (1) and the Natural Resources Conservation Authority Act, 1991.

It is of note that areas of forests reported for 2000 and 2005 in the *FAO Global Forest Resource Assessment* (FRA) will differ from those reported in this report to the extent that estimates of the forest cover in the "Mixed" category are included in this report but were not calculated in the FRA report. The reasons these areas are included in this report is that they represent a significant amount of carbon and an assessment of the mean volume per hectare for these areas was calculated and reported in the *National Forest Inventory Report 2003.* This made it possible to calculate the biomass for these areas. The reasons these areas were not reported in the FRA 2005 report are documented in that report.

Table 2.43 shows the base data that were used in this inventory. The area for the reporting years 2000 and 2005 was estimated using linear extrapolation of the 1989 and 1998 data.

Table 2.43: Land Use Classes Areas (ha) converted to GHG Classes[16]

Code	National class	GHG Inventory Classes	Area (ha)			
			Base Years			
			1989	1998	Difference	Loss/Gain (%)
1	2	3	4	5	6	7
Forests land use						
PF	Closed broadleaf	Forest Land	88717	88231	-486	-0.55
SF	Disturbed broadleaf	Forest Land	177254	174725	-2529	-1.45
WL	Tall open dry	Forest Land	42125	41998	-127	-0.30
SL	Short open dry	Forest Land	12083	12104	21	0.17
SW	Swamp	Forest Land	2358	2247	-111	-4.94
MG	Mangrove	Forest Land	9751	9731	-20	-0.21
PP	Pine plantation	Forest Land	4956	4287	-669	-15.61
HP	Other Species Plantation	Forest Land	3900	3900	0	0.00
		SUB-TOTAL	**341144**	**337223**	-3921	
Mixed Land Use						
SC	Disturbed Broadleaf Forest &	75% Forest Land	125129	124466	-663	-0.53
SC	Non-Forest land Use	25% Otherland	41710	41489	-221	-0.53
CS	Non-Forest land Use &	75%: 76% Otherland	94283	94414	131.67	0.14
CS	Non-Forest land Use &	75%: 24% Grassland	29773	29815	41.58	0.14
CS	Disturbed Broadleaf Forest	25% Forest Land	41352	41410	57.75	0.14
		SUB-TOTAL	**332246**	**331593**	-653	
Non-Forest land use						
	Non-Forest land use	20% Cropland 64% Grassland 3% Wetlands 12% Settlements 1% Otherland	423025	427600	4575	1.07
		SUB-TOTAL	**423025**	**427600**	4575	
		TOTAL	**1096416**	**1096416**		

It was stated that a spatially explicit land use conversion matrix for 1989-98 was reported in Evelyn and Camirand, 2003. This matrix is reproduced in Table 2.44 below. It should be noted that several of the forest land use classes are degraded to a lower class. For example, 369 ha from Closed broadleaf forest ($194m^3$/ha) was degraded to Disturbed broadleaf forest ($165m^3$/ha) and 2018ha from Disturbed broadleaf forest was degraded to Disturbed broadleaf forest and No-forest ($94m^3$/ha). However, it is difficult to accurately account for this loss because, as was stated above, net annual increments (m^3 ha-1 yr-1) for these country specific vegetation types are not available. An attempt is made to document this loss in Table 2.44.

[16] Modified and extended from Camirand and Evelyn, (2004)

Table 2.44: Land use/cover conversion matrix for Jamaica, 1989-98[17]

To \ From			GHG Class	Land use/cover 1989 (Ha)																					Total Gain (ha)	Net Loss/Gain
				Forest							Mixed						Non-forest									
				PF	SF	WL	SL	SW	MG	PP	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	Forest Land																						0	-669
	Mixed	BB	Grassland		3							139				46									188	188
		BC	75% Grassland, 25% OtherLand							16			193							90					299	-773
		BF	75% Grassland, 25% Forest Land		241					172		156													569	376
		BS	75% Other Land, 25% Forest Land		229										230	911									1370	1370
		CS	75% OtherLand, 25% Forest Land		359	28				385		378				1301	1			30			60		2542	-931
		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

17 Modified from Evelyn and Camirand (2003)

Table 2.45 summarizes the annual losses and gains by land use class and Table 2.46 shows a derived conversion matrix by GHG classes from the matrix in Table 2.44.

Figures in column 4 of Table 2.45 are derived from the Losses in Table 2.44. For example, for PF, the total loss for that Class in Table 2.44 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 derived from the Gains in Table 2.44. For example, for SF, 75% of the figure for CS (since 25% is already forest) is added to the figure for FC ((106 x 0.75) + 62)/9 = 15.8 ha. For the transfers in column 6, the figures are also derived from the Gains (transfers) in Table 2.44. For example, for SF, the figures from the forest types PF, PP and 25% of CS are added together (396+7 + (106 x 0.25))/9 = 47.8 ha.

Table 2.45: Annual land use loss, transfer and gain

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	7
Forest	PF	Forest Land	-54.0			-54.0
	SF	Forest Land	-344.7	15.8	47.8	-281.2
	WL	Forest Land	-14.8	0.7		-14.1
	SL	Forest Land	-23.0	25.2		2.2
	SW	Forest Land	-12.3			-12.3
	MG	Forest Land	-6.9	4.4	0.1	-2.4
	PP	Forest Land	-74.4			-74.4
	HP		0.0			0.0
Sub-total			**-530.2**	**46.1**	**47.8**	**-436.3**
Mixed	SC	75% Forest Land	-288.0	28.9	185.6	-73.5
		25% Otherland	-96.0	61.6	9.9	-24.5
	CS	75% Otherland	-299.8	243.2	91.2	34.5
		75% Grassland	-94.7	45.0	48.1	-1.6
		25% Forest Land	-131.5	17.4	107.1	-7.0
Sub-total			**-910.1**	**396.1**	**441.9**	**-72.2**
Non-Forest	Mixed	20% Cropland	-103.4	14.0		-89.4
		64% Grassland	-243.2	357.1	31.0	144.9
		3% Wetlands	-13.1	5.2		-7.9
		12% Settlements	-0.1	39.1		39.0
		1% Otherland		271.1	150.7	421.8
Sub-total			**-359.8**	**686.5**	**181.7**	**508.4**
GRAND TOTAL			**-1800**	**1129**	**671**	**0**

Figures in Table 2.46 are derived from column 5 in Table 2.45 which, as was stated above, is derived from the Gains from other land use in Table 2.44. For example, the figure for CropLand to Forest Land (25.2 ha) is the figure of PC to SL (227 ha) in Table 2.44 divided by 9 years, which is also the figure for SL in column 5 in Table 2.45.

Table 2.46: Matrix showing annual land use conversion by GHG Class

TO/FROM	FOREST LAND	CROP LAND	GRASS LAND	WET LAND	SETTLEMENT	OTHER LANDS	TOTAL
Forest Land		25.2	26.6	7.5	0.03	33.1	92.43
Crop Land			13.7	0.3			14.0
Grass Land	205.8	73.0				123.4	402.2
Wet Land		5.2					5.2
Settlements	26.6		5.5			7.1	39.2
Other Lands	346.8		223.7	5.3	0.10		575.9
Total	579.2	103.4	269.5	13.1	0.13	163.6	1128.93

Table 2.47 summarizes the land use areas according to the IPCC Inventory classes. Figures are derived from Tables 2.43 and 2.45. For example, for Forest Land remaining Forest Lands in 1999, the figure (502489 ha) is derived as follows: (337223+124466+41410)-(436.3+73.5+7.0)-(46.1+28.9+17.4). For the area converted to forest (92), this figure is derived from Table 2.45 (46.1+28.9+17.4). These figures were calculated in a spreadsheet and rounded therefore the decimals may differ.

Table 2.47: Summary of land use areas according to IPCC Inventory Classes (2000-05)

GHG Inventory Classes	Area (ha)					
	2000	2001	2002	2003	2004	2005
FL remaining FL	501880	501271	500661	500052	499443	498834
Land converted to FL	92	92	92	92	92	92
CL remaining CL	85327	85238	85148	85059	84970	84880
Land converted to CL	14	14	14	14	14	14
GL remaining GL	303456	303692	303835	303978	304121	304265
Land converted to GL	402	402	402	402	402	402
WL remaining WL	12807	12799	12791	12783	12776	12768
Land converted to WL	5	5	5	5	5	5
SL remaining SL	51351	51390	51429	51468	51507	51546
Land converted to SL	39	39	39	39	39	39
OL remaining OL	140466	140898	141422	141947	142471	142995
Land converted to OL	576	576	576	576	576	576
TOTAL	1096416	1096416	1096416	1096416	1096416	1096416

The *IPCC 2006 Guidelines* advise that the default limit to account for Lands Converted to Forest Land is 20 years. Lands being converted to forests land since 1989 were reported in Evelyn and Camirand (2003) and the Forestry Department has observed this trend in other areas of the country since then (see, for example, WRC, 2007). Hillside farms are being abandoned as the older generation of farmers decreases and the current generation of small farmers shows no interest in continuing to farm these lands. Tables 2.46 and 2.47 project 92.0 ha has being converted to forests lands annually.

For the 5-year period, (2000-2005) these areas are in the early succession stages of forest development and do not fit the *IPCC Guidelines*. Whether these areas will be allowed to go through the succession stages and become well stocked forests is to be seen. These lands are considered fallow (CropLand: annuals) but were placed in the GrassLand category of CS (see Table 2.48; Non-Forest land Use &

Table 2.48: Summary of total annual land use areas from country specific data

Code	National Data	GHG Inventory Classes	Area (ha)			Area (ha)					
			Base Years			Estimations Based on Extrapolation					
			1989	1998	1999	2000	2001	2002	2003	2004	2005
Forests land use											
PF	Closed broadleaf	Forest Land	88717	88231	88177	88123	88069	88015	87961	87907	87853
SF	Distributed broadleaf	Forest Land	177254	174725	174428	174131	173834	173537	173240	172943	172646
WL	Tall open dry	Forest Land	42125	41998	41983	41968	41954	41939	41924	41909	41894
SL	Short open dry	Forest Land	12083	12104	12081	12058	12035	12012	11989	11966	11943
SW	Swamp	Forest Land	2358	2247	2235	2222	2210	2198	2185	2173	2161
MG	Mangrove	Forest Land	9751	9731	9724	9717	9711	9704	9697	9690	9683
PP	Pine plantation	Forest Land	4956	4287	4213	4138	4064	3989	3915	3841	3766
HP	Other Species Plantation	Forest Land	3900	3900	3900	3900	3900	3900	3900	3900	3900
SUB-TOTAL			341144	337223	336741	336258	335776	335294	334811	334329	333847

Table 2.48: Summary of total annual land use areas from country specific data (continued)

Mixed Land Use												
SC	Disturbed Broadleaf Forest &	75% Forest Land		125129	124466	124363	124261	124158	124056	123953	123851	123748
	Non-Forest land Use	25% Otherland		41710	41489	41464	41439	41415	41390	41366	41341	41317
CS	Non-Forest land Use &	75%	76% Otherland 24% Grassland	94283	94414	94449	94483	94518	94645	94771	94898	95025
	Disturbed Broadleaf Forest	25% Forest Land		29773	29815	29906	29997	30087	30086	30084	30083	30081
SUB-TOTAL				332246	331593	331567	331541	331515	331489	331463	331436	331410
Non-Forest land use												
	Non-Forest land Use	20% Cropland		84605	85520	85431	85341	85252	85162	85073	84984	84894
		64% Grassland		270736	273664	273809	273954	274099	274244	274389	274533	274678
		3% Wetlands		12691	12828	12820	12812	12804	12797	12789	12781	12773
		12% Settlements		50763	51312	51351	51390	51429	51468	51507	51546	51585
		1% Otherland		4230	4276	4698	5120	5541	5963	6385	6807	7229
SUB-TOTAL				423025	427600	428108	428617	429125	429634	430142	430651	431159
TOTAL				1096416	1096416	1096416	1096416	1096416	1096416	1096416	1096416	1096416

Table 2.49: Area (%) of Jamaica by Land Use, Holdridge Life Zone[18] 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**

[18] Modified and extended from Camirand and Evelyn, (2004)

Disturbed Broadleaf Forest) since it was more applicable at this time. It could be argued that since some of these areas were originally agriculture, they may go back into agriculture. However, the current trend suggests that they will be left to become Forest Land in the future. There will be no carbon accounting for these lands in this report since the vegetation age is well below 20 years.

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 a percentage of the relevant land use they affect in Table 2.49.

Table 2.50 summarizes the annual removals. Figures for the removals from public lands are well documented in the Forestry Department's records. The figures for private lands are unknown. An assumption is therefore made that the removals from privately owned lands are according to the ratio of publicly owned lands to privately own lands in Jamaica. It will be noted that the removals for 2005 are significantly higher than the previous year. This is due to salvaging operations from Hurricane Ivan in September 2004. No reliable assessment was available of the total area of forest that was lost from this event.

The figure for annual fuel wood use in Jamaica is unknown. Estimates are therefore used from FAOSTAT and are shown in Table 2.50. The Jamaican Forestry Department does not consider these estimates as being reliable, however. FAO estimates these quantities using a statistical model which relates wood fuel and charcoal consumption to several variables such as population income and distribution, forest cover and land area (FAO, 2005).

If these estimates are related to area, it is evident that the figures are grossly overestimated. For example, dividing the volume for the year 2000 by the mean volume per hectare ($105m^3/ha$) for all the forest types except the plantations given in Table 2.49 above yields an area of 5,702 hectares cleared for fuel wood in the year 2000. This more than 17 times the annual rate of deforestation estimated by Evelyn and Camirand (2003). It could be argued that some of this volume is coming from the degradation for yam sticks that is taking place in the Jamaican forest, which is unquantified, but nothing of this magnitude has been observed.

For the calculations of fuel wood removal, the FAO figures will therefore be divided by 17 and further reduced by one half which makes the estimated average annual area of land harvested for fuel wood (including yam sticks) approximately 162 ha (15 – 20000 m^3) or about half the estimated area deforested in 1998 (Evelyn and Camirand, 2003) . This is acceptable to the Forestry Department at this time until a proper study is done.

Table 2.51 estimates the annual total losses from removals such as logging, fuel wood extractions and minor disturbances (such as small fires). This Table is derived from the land use changes documented in Table 2.44. It does not contain the disturbances caused by hurricane Ivan in 2004 however. This was estimated and then added for the carbon loss calculations.

Table 2.50: Summary of annual removals (2000-05)

Wood Removal - on Forest Reserves & Public Lands (m^3)							Volume (m^3/ha)	Area (Ha)					
Year	2000	2001	2002	2003	2004	2005		2000	2001	2002	2003	2004	2005
Species	**Carib pine plantations**							**Carib pine**					
Public	134.6	171.3	301.1	203.4	1038.3	2021.8	119	1.13	1.43	2.52	1.70	8.69	1.00
Private	15.7	20.0	35.1	23.7	121.1	235.8	119	0.13	0.17	0.29	0.20	1.01	1.00
Sub-total	**150.2**	**191.3**	**336.2**	**227.1**	**1159.4**	**2257.6**		**1.26**	**1.60**	**2.81**	**1.90**	**9.71**	**2.00**
Species	**Hardwoods - natural forest & plantation**							**Hardwoods**					
Public	347.6	287.1	290.7	210.3	1619.3	182.0	148	2.35	1.94	1.97	1.42	10.95	1.00
Private	617.9	510.4	516.8	373.8	2878.8	323.6	148	4.18	3.45	3.50	2.53	19.47	1.00
Sub-total	**965.5**	**797.5**	**807.5**	**584.1**	**4498.1**	**505.6**		**6.53**	**5.40**	**5.46**	**3.95**	**30.43**	**2.00**
Species	**Fuelwood*- public and private**												
FAOSTAT	~~598710~~	~~591425~~	~~584228~~	~~577119~~	~~570096~~	~~563159~~		~~5702.0~~	~~5632.6~~	~~5564.1~~	~~5496.4~~	~~5429.5~~	~~5363.4~~
Adjusted	17609	17395	17183	16974	16768	16564	105	167.71	165.67	163.65	161.66	159.69	157.75

Table 2.51: Summary of annual removals

Land use Class			Annual total Loss from Disturbance						Annual loss to other land use by GHG Inventory Classes sub-categories									
National Class		GHG Classes	Loss to other land use		Degraded to other forest type		Total Loss		Tropical rain forest		Tropical moist deciduous forest		Tropical dry forest		Tropical mountain		TOTAL	
			Area (ha)	Vol (m^3)	Area (ha)	Vol (m^3)	Area (ha)	Vol (m^3)	Area (ha)	Vol (m^3)	Area (ha)	Vol (m^3)	Area (ha)	Vol (m^3)	Area (ha)	Vol (m^3)	Area (ha)	Vol (m^3)
1		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Forest	PF	Forest Land	2.5	485.0	51.5	2026.0	54.0	**2511.0**	1.0	1002.5	0.3	309.2	0.1	78.1	1.1	1121.2	2.5	**2511.0**
	SF	Forest Land	153.4	25315.1	236.0	14218.1	389.4	**39533.3**	21.0	5406.7	32.9	8482.0	64.4	16592.1	35.1	9052.5	153.4	**39533.3**
	WL	Forest Land	14.0	533.0	0.8	-21.7	14.8	**511.3**	0.1	2.7	0.3	10.7	13.0	472.6	0.7	25.3	14.0	**511.3**
	SL	Forest Land	22.9	755.7			22.9	**755.7**	0.0	0.0	0.0	0.0	22.9	755.7	0.0	0.0	22.9	**755.7**
	SW	Forest Land	12.3	2226.3			12.3	**2226.3**	0.0	0.0	0.6	106.0	11.7	2120.3	0.0	0.0	12.3	**2226.3**
	MG	Forest Land	6.9	545.1			6.9	**545.1**	0.0	0.0	0.2	12.4	6.7	532.7	0.0	0.0	6.9	**545.1**
	PP	Forest Land	58.1	8602.5	16.3	783.4	74.4	**9385.9**	49.2	7941.9	3.0	481.3	0.0	0.0	6.0	962.7	58.1	**9385.9**
	HP	Forest Land	0.0	0.0			0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
		Sub-total	**270.2**	**38462.7**	**304.5**	**17005.8**	**574.7**	**55468.5**	**71.2**	**14353.8**	**37.2**	**9401.6**	**118.8**	**20551.5**	**42.9**	**11161.6**	**270.2**	**55468.5**
Mixed	**SC**	75% Forest Land	226.5	21288.7	61.5	1721.7	288.0	**23010.4**	19.0	1930.2	37.5	3814.8	88.4	8982.3	81.5	8283.1	226.5	**23010.4**
		25% Otherland																
	CS	75% Otherland																
		75% Grassland																
		25% Forest Land	82.6	5450.0	36.0	-570.0	118.5	**4880.0**	10.5	622.9	19.8	1168.4	27.5	1623.4	24.8	1465.3	82.6	**4880.0**
		Sub-total	**309.1**	**26738.6**	**97.5**	**1151.8**	**406.5**	**27890.4**	**29.5**	**2553.1**	**57.3**	**4983.2**	**115.9**	**10605.7**	**106.3**	**9748.4**	**309.1**	**27890.4**
Non-Forest	**Mixed**	20% Cropland																
		64% Grassland																
		3% Wetlands																
		12% Settlements																
		1% Otherland																
		Sub-total	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
		GRAND TOTAL	**579.2**	**65201.3**	**402.0**	**18157.6**	**981.2**	**83358.9**	**100.8**	**16906.9**	**94.6**	**14384.8**	**234.7**	**31157.2**	**149.2**	**20910.0**	**579.2**	**83358.9**

National estimates of volume and biomass between 1989 and 2005 have been reported in several publications since the year 2000 (Forest Department, 2001b; Camirand and Evelyn, 2004; FRA, 2005). 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 2.52 below shows the estimates for 1998.

Table 2.52: Total volume and aboveground living biomass by forest type[19]

Code	National class	GHG Inventory Classes		1998	Volume (m^3/ha)	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	194	17089	22974
SF	Disturbed broadleaf	Forest Land		174725	165	28910	42090
WL	Tall open dry	Forest Land		41998	38	1586	4876
SL	Short open dry	Forest Land		12104	23	276	1095
SW	Swamp	Forest Land		2247	181	407	566
MG	Mangrove	Forest Land		9731	79	765	1623
PP	Pine plantation	Forest Land		4287	119	512	339
HP	Other Species Plantation	Forest Land		3900	148	577	889
		SUB-TOTAL		**337223**		**50121**	**74453**
Mixed Land Use							
SC	Disturbed Broadleaf Forest &	75% Forest Land		124466	94	15535	30173
	Non-Forest land Use	25% Otherland		41489			
CS	Non-Forest land Use &	75%	76% Otherland	94414			
			24% Grassland	29815			
	Disturbed Broadleaf Forest	25% Forest Land		41410	66	9017	20840
		SUB-TOTAL		**331593**		**24552**	**51012**
Non-Forest land use							
	Non-Forest land use	20% Cropland 64% Grassland 3% Wetlands 12% Settlements 1% Otherland		427600			
		SUB-TOTAL		**427600**			0
		TOTAL		**1096416**		**74674**	**125466**

Brown 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* (Brown, 1997). Instead, volume over bark per hectare (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 so that MAI for each forest type will be available in the future.

Jamaica has a fairly good soils database. This is in a GIS database and was easily extracted and formatted to the GHG soil classes with some help from the Rural Physical Planning Unit within the Ministry of

[19] Source: Table 25 in Camirand and Evelyn, (2004). Note: Biomass estimates were incorrectly calculated in source and are corrected here

Agriculture and Land. The soils GIS dataset was intersected with the land use dataset to produce the estimated areas shown in Table 2.53.

Table 2.53: Area (%) of Jamaica by IPCC Soil Classes

Area% (ha) of land by Land use and IPCC Soil Classes							
Land Use Code	National class	GHG Inventory Classes	High Activity Clay	Low Activity Clay	Sandy soils	Wetland Soil	Grand Total
Forests land use							
PF	Closed broadleaf	Forest Land	7.82	0.22	0.00	0.00	8.04
SF	Disturbed broadleaf	Forest Land	14.92	0.93	0.00	0.00	15.94
WL	Tall open dry	Forest Land	3.72	0.12	0.00	0.00	3.84
SL	Short open dry	Forest Land	1.03	0.09	0.00	0.00	1.11
SW	Swamp	Forest Land	0.05	0.14	0.01	0.00	0.20
MG	Mangrove	Forest Land	0.88	0.00	0.01	0.00	0.89
PP	Pine plantation	Forest Land	0.28	0.11	0.00	0.00	0.39
HP	Other Species Plantation	Forest Land	0.27	0.09	0.00	0.00	0.36
		Sub Total	**28.96**	**1.71**	**0.02**	**0.00**	**30.76**
Mixed							
SC	Disturbed Broadleaf	75% Forest Land	10.27	1.06	0.01	0.02	11.35
	Non-Forest land	25% Otherland	3.42	0.35	0.00	0.01	3.78
CS	Non-Forest land Use &	75% Otherland	7.30	0.68	0.00	0.00	7.98
		75% Grassland	2.30	0.21	0.00	0.00	2.52
	Disturbed Broadleaf Forest	25% Forest Land	4.21	0.39	0.00	0.00	4.61
		Sub Total	**27.51**	**2.70**	**0.01**	**0.02**	**30.24**
Non-Forest Land Use							
	Non-Forest land use	20% Cropland	5.20	2.49	0.02	0.08	7.80
		64% Grassland	16.65	7.97	0.08	0.27	24.96
		3% Wetlands	0.78	0.37	0.00	0.01	1.17
		12% Settlements	3.12	1.49	0.01	0.05	4.68
		1% Otherland	0.26	0.12	0.00	0.00	0.39
		Sub Total	**26.01**	**12.45**	**0.12**	**0.42**	**39.00**
		Total	**82.48**	**16.85**	**0.15**	**0.44**	**100.00**

Forest Land Remaining Forest Land and Land Converted to Forest Land

For the calculation of estimates for Forest Land Remaining Forest Land (FF) and Land Converted to Forest Land (LF), the 2006 *IPCC Guidelines for NGHG Inventories* advise firstly that:

> *The calculations (should) distinguish between two broad management practices: intensive (e.g., plantation forestry with site preparation, planting of selected species and fertilization) and extensive (natural regeneration with minimum human intervention). These categories can also be refined according to national circumstances, for example based on stand origin (e.g., natural or artificial regeneration, restocking, promotion of natural re-growth, etc.), climate, species, management practice, etc.*

As per the 2006 IPCC Guidelines, Jamaica's two forest plantation categories, Caribbean Pine and Other Species, can be considered intensively managed (e.g., plantation forestry with site preparation, planting of selected species and fertilization), while all the other forest categories can be considered extensively managed, i.e. natural regeneration with minimum human intervention.

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). Therefore, for the calculation of the estimated annual increase in biomass carbon stocks due to biomass growth and loss in Forest Land, a combination of both Tier1 and Tier 2 methodologies was used.

The area and volume figures used in these tables are outlined in Tables 2.54 to 2.57 below. Table 2.58 summarizes the data from the Category Tables. The forested areas for each year in Table 2.54 are derived using the methodology outlined in Table 2.59. The values for Table 2.55 are taken from Table 2.50. It is estimated that the extracted timber came from the Tropical rain forest where most of the plantations are located (see Table 2.49).

The data in Table 2.57 are derived from Tables 2.50 and 2.51. For example, the value for Tropical rain forest – natural forest for the year 2000 is calculated by subtracting the value for the plantations from the grand total in column 9 (100.8-49.2 ha). The value for Tropical rain forest – pine plantations is calculated by subtracting the value for the area of pine plantations extracted (1.26 ha) in 2000 which is shown in Table 2.50 from the total area of pine loss by disturbance in Table 2.51, column 17 (15.1 ha).

The IPCC 20 year limit on some of the estimates for soils carbon pool, such as the annual change in carbon stocks in mineral soils on Land Converted to Forest Land, also exclude these estimates from the inventory. Organic soils are characterized by their high carbon composition of plant material and high water tables. Organic C is usually concentrated in the top 30 cm of a soil profile. In Jamaica, only about 2 of the 186 soil types are classified as organic with only one classified as drained.

The area of Forest Land Remaining Forest Land and Land Converted to Cropland was reported in Table 2.47. Table 2.58 below summarizes the carbon estimated for Forest Land remaining Forest Land only.

Table 2.54: Areas used for the calculation in 3B1a: Annual increase in carbon stocks in biomass

Area of Forest Land Remaining Forest Land								
Land-use category		Subcategories for reporting year	Area of Forest Land Remaining Forest Land (ha)					
			YEAR					
Initial land use	Land use during reporting year		**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
FL	FL	Tropical rain forest - natural forest	74920	74846	74772	74698	74624	74550
		Tropical rain forest - other species plantations	1003	1003	1003	1003	1003	1003
		Tropical rain forest - pine plantations	3502	3439	3376	3313	3250	3187
		Tropical moist deciduous forest	79916	79822	79727	79633	79539	79445
		Tropical moist deciduous forest- other species plantations	1114	1114	1114	1114	1114	1114
		Tropical moist deciduous forest - pine plantations	212	208	205	201	197	193
		Tropical dry forest	200558	200329	200099	199870	199640	199411
		Tropical mountain systems	138448	138311	138174	138037	137900	137763
		Tropical mountain systems - other species plantations	1783	1783	1783	1783	1783	1783
		Tropical mountain systems - pine plantations	424	417	409	402	394	386
Total			**501880**	**501271**	**500661**	**500052**	**499443**	**498834**

Table 2.45: Volumes used for the calculation in 3B1a: Loss of carbon from wood removals

Forest Land Remaining Forest Land: Loss from wood removals (logging)								
Land-use category		Subcategories for reporting year	Annual wood removal (m^3 yr^{-1})					
			YEAR					
Initial land use	Land use during reporting year		2000	2001	2002	2003	2004	2005
FL		Tropical rain forest - other species plantations	966	798	808	584	4498	506
		Tropical rain forest - pine plantations	150	191	336	227	1159	2258
Total			**1116**	**989**	**1144**	**811**	**5657**	**2763**

Table 2.56: Volumes used for the calculation in 3B1a: Loss of carbon from fuelwood removals

Forest Land Remaining Forest Land: Loss from fuelwood removals				
Land-use category		Subcategories for reporting year	Year	Annual volume of fuelwood removal as tree parts (m^3 yr^{-1})
Initial land use	Land use during reporting year			
FL	FL	Mixed (Tropical deciduous and dry forest)	**2000**	13216
			2001	13056
			2002	12897
			2003	12740
			2004	12585
			2005	12432

Values in Table 2.56 are taken from Table 2.50.

Table 2.57: Areas used for the calculation in 3B1a: Loss of carbon from disturbanc*e*

Forest Land Remaining Forest Land: Loss from disturbance								
Land-use category		Subcategories for reporting year	Area affected by disturbances (ha y^{r-1})					
			YEAR					
Initial land use	Land use during reporting year		2000	2001	2002	2003	2004	2005
FL	FL	Tropical rain forest - natural forest	51.6	51.6	51.6	51.6	51.6	49.6
		Tropical rain forest - pine plantations	56.9	56.5	55.3	56.2	48.4	56.1
		Tropical moist deciduous forest	6.0	7.1	8.1	9.1	10.1	11.1
		Tropical dry forest	149.1	150.2	151.2	152.2	153.2	154.2
		Tropical mountain systems	143.3	143.3	143.3	143.3	143.3	143.3
Total			**406.9**	**408.6**	**409.5**	**412.4**	**406.6**	**414.3**

Table 2.58: Carbon accounting for Forest Land Remaining Forest Land and Land Converted to Forest Land

CATEGORY	YEARS					
	2000	2001	2002	2003	2004	2005
3B1a: ***Forest Land Remaining Forest Land***						
Average annual increase in carbon (Gg CO_2)	1539.74	1537.49	1535.25	1533.01	1530.77	1528.53
Annual decrease in carbon stocks due to biomass loss (wood-removals + fuelwood + disturbancess)(Gg CO_2)	14.58	14.27	14.34	14.08	18.26	14.79
Annual carbon loss from drained organic soils	0.00	0.00	0.00	0.00	0.00	0.00
3B1b : ***Land Converted to Forest Land***						
Annual increase in carbon stocks in biomass (includes above- and below-ground biomass)	0.00	0.00	0.00	0.00	0.00	0.00
Annual decrease in carbon stocks due to biomass loss (wood-removals + fuelwood + disturbancess)	0.00	0.00	0.00	0.00	0.00	0.00
Annual change in carbon stocks in dead organic matter due to land conversion	0.00	0.00	0.00	0.00	0.00	0.00
Annual change in carbon stocks in mineral soils	0.00	0.00	0.00	0.00	0.00	0.00
Annual change in carbon stocks in organic soils	0.00	0.00	0.00	0.00	0.00	0.00

Cropland Remaining Cropland and Land Converted to Cropland

Only the accounting for carbon stored or loss in the biomass of croplands that contain perennial woody vegetation is required by the *IPCC 2006 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 the estimation of the carbon changes in cropland biomass in Jamaica, the Tier 1 approach was used. The area of Cropland Remaining Cropland and Land Converted to Cropland is reported in Table 2.47. Tables 2.59 and 2.60 give the estimated areas used. Table 2.61 summarizes the estimated carbon changes for this category.

The area calculations in Table 2.59 are fairly straightforward. For example, for each year, the percentage area of Cropland which is classified as Tropical rain forest in Table 2.49, column 15, is divided by the total in Column 19 and then multiplied by the area of CropLand remaining CropLand for the year 2000 in Table 2.47. Values in Table 2.60 are taken from Table 2.46 and the land use category is estimated to be Tropical dry forest since most of the cropland falls into that category. Table 2.61 summarizes the carbon estimates for CropLand remaining CropLand.

Table 2.59: Areas used for the calculation in 3B2a: CropLand remaining CropLand

Area of Cropland Remaining Cropland								
Land-use category		Subcategories for reporting year	Annual area of Cropland with perennial woody biomass (ha)					
Initial land use	Land use during reporting year		YEAR					
			2000	**2001**	**2002**	**2003**	**2004**	**2005**
CL	CL	Tropical rain forest - natural forest	7725	7717	7709	7701	7693	7685
		Tropical moist deciduous forest	10986	10974	10963	10951	10940	10928
		Tropical dry forest	46264	46215	46167	46118	46070	46021
		Tropical mountain systems	20352	20331	20310	20288	20267	20246
Total			**85327**	**85238**	**85148**	**85059**	**84970**	**84880**

Table 2.60: Areas used for the calculation in 3B2b: Land Converted to CropLand

Land Converted to Cropland: Annual change in carbon stocks in biomass			
Land-use category		Subcategories for reporting year	Annual area of Land Converted to Cropland
Initial land use	Land use during reporting year		YEAR
			2000 - 2005
GL	CL	Tropical dry forest	13.7
WL	CL	Tropical dry forest	0.31

Table 2.61: Carbon accounting for Cropland Remaining Cropland and Land converted to Cropland

CATEGORY	YEARS					
	2000	2001	2002	2003	2004	2005
3B2a: Cropland Remaining Cropland						
Annual change in carbon stocks in biomass(Gg CO_2)	-1224.39	-1225.84	-1227.29	-1228.75	-1230.20	-1231.65
Annual change in carbon stocks in mineral soils	0.00	0.00	0.00	0.00	0.00	0.00
Annual change in carbon stocks in organic soils	0.00	0.00	0.00	0.00	0.00	0.00
3B2b: Land Converted to Cropland						
Annual change in carbon stocks in biomass (Gg CO_2)	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08
Annual change in carbon stocks in dead organic matter due to land conversion	0.00	0.00	0.00	0.00	0.00	0.00
Annual change in carbon stocks in mineral soils	0.00	0.00	0.00	0.00	0.00	0.00
Annual change in carbon stocks in organic soils	0.00	0.00	0.00	0.00	0.00	0.00

<u>Grassland Remaining Grassland and Land Converted to Grassland</u>

The area of Grassland Remaining Grassland is reported in Table 2.47. Table 2.62 summarizes the carbon estimated for these areas.

Table 2.62: Grassland Remaining Grassland: Annual change in carbon stocks in biomass, 2000-06

CATEGORY	YEARS					
	2000	2001	2002	2003	2004	2005
303a: Grassland Remaining Grassland						
Annual change in carbon stocks in mineral soils	0.00	0.00	0.00	0.00	0.00	0.00
Annual change in carbon stocks in organic soils (Gg CO2)	0.00	0.00	0.00	0.00	0.00	0.00
303b: Land converted to Grassland						
Annual Change in carbon stocks in biomass (Gg CO2)	0.40	0.40	0.40	0.40	0.40	0.40
Annual change in carbon stocks in dead organic matter due to land conversion (Gg CO2)	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04
Annual change in carbon stocks in mineral soils	0.00	0.00	0.00	0.00	0.00	0.00
Annual change in carbon stocks in organic soils	0.00	0.00	0.00	0.00	0.00	0.00

Wetland Remaining Wetland and Land Converted to Wetland

The area of Wetland Remaining Wetland is reported in Table 2.47. Table 2.63 summarizes the carbon estimated for these areas.

Table 2.63: Carbon accounting for Wetland Remaining Wetland and Land converted to Wetland (2000-06)

CATEGORY	YEARS					
	2000	2001	2002	2003	2004	2005
3B4ai :*Wetlands Remaining Wetlands*						
CO_2-C emissions from managed peatlands	0.00	0.00	0.00	0.00	0.00	0.00
N_2O Emissions from peatlands during peat extraction	0.00	0.00	0.00	0.00	0.00	0.00
3B4bii: *Land converted to Wetlands*						
CO_2 Emissions from Land Converted to Flooded land	0.00	0.00	0.00	0.00	0.00	0.00
N_2O Emissions from land converted for peat extraction	0.00	0.00	0.00	0.00	0.00	0.00
CO_2 Emissions from Land Converted to Flooded land	0.00	0.00	0.00	0.00	0.00	0.00

Settlement Remaining Settlement and Land Converted to Settlement

The area of Settlement Remaining Settlement is reported in Table 2.47. Table 2.64 summarizes the carbon estimated for these areas.

Table 2.64: Carbon accounting for Settlement Remaining Settlement and Land converted to Settlement (2000-06)

CATEGORY	YEARS					
	2000	2001	2002	2003	2004	2005
3B5a: *Settlement Remaining settlement*						
Annual change in carbon stocks in organic soils	0.00	0.00	0.00	0.00	0.00	0.00
3B5b: *Land converted to Settlement*						
Annual change in carbon stocks in biomass (Gg CO_2)	-0.048	-0.048	-0.048	-0.048	-0.048	-0.048
Annual change in carbon stocks in dead organic matter due to land conversion (Gg CO_2)	0.059	0.059	0.059	0.059	0.059	0.059
Annual change in carbon stocks in mineral soils	0.000	0.000	0.000	0.000	0.000	0.000
Annual change in carbon stocks in organic soils	0.000	0.000	0.000	0.000	0.000	0.000

Other Land Remaining Other Land and Land Converted to Other Land

The area of Other Land Remaining Other Land is reported in Table 2.47. Table 2.65 summarizes the carbon estimated for these areas.

Table 2.65: Carbon accounting for Other Land Remaining Other Land and Land converted to Other Land (2000-06)

CATEGORY	YEARS					
	2000	2001	2002	2003	2004	2005
3B6b: *Land converted to Other Land*						
Annual change in carbon stocks in biomass (Gg CO_2)	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57
Annual change in carbon stocks in mineral soils	0.00	0.00	0.00	0.00	0.00	0.00
Annual change in carbon stocks in organic soils	0.00	0.00	0.00	0.00	0.00	0.00

Emissions from Biomass Burning

Biomass burning activities include burning of fields prior to harvesting, brush and forest fires, clearing of land for agriculture and drug interdiction activities. There are reliable data on the burning of sugar cane fields (area burned) which ranged between about 27,000 and 38,000 hectares between 2000 and 2005. The amount of sugar cane burned before harvesting was assumed to be 90% of the area reaped. The area of ganja[20] destroyed (assumed to be by burning) was relatively small (between 300 and 500 ha between 2000 and 2005) and was neglected. The estimated emissions from biomass burning for 2000-05 are shown in Table 2.66.

Table 2.66: Emissions from Biomass Burning (Sugar Cane harvesting) (2000-05)

Years	Area burnt (ha)	CH_4 emissions from fire (tonnes CH_4)	CO emissions from fire (tonnes CO)	N_2O emissions from fire (tonnes N_2O)	NOx emissions from fire (tonnes NOx
2000	32298.3	0.453468	15.45151	0.011757	0.419878
2001	30803.4	0.43248	14.73635	0.011212	0.400444
2002	27522.9	0.38642	13.16696	0.010018	0.357798
2003	27858.6	0.391135	13.32755	0.010141	0.362162
2004	24824.7	0.348539	11.87614	0.00936	0.322721
2005	25175.7	0.353467	12.04405	0.009164	0.327284

Uncertainties, Quality Assurance and Control

Table 2.67 summarizes the uncertainty analysis for the forestry subsector.

20 PIOJ Economic and Social Survey of Jamaica Reports 2000 to 2006.

Table 2.67: Approach 1 Uncertainty Analysis for the Forestry subsector

APPROACH 1 UNCERTAINTY ANALYSIS FOR JAMAICA, 2005												
A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC category	Gas	Base year emissions or removals	Year *t* emissions or removals	Activity data uncertainty	Emission factor /estimation parameter uncertainty	Combined uncertainty	Contribution to variance by source/sink category in year *t*	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
				Note A	Note A	$\sqrt{E^2+F^2}$	$\frac{(G \bullet D)^2}{(\sum D)^2}$	Note B	$\frac{D}{\sum C}$	I • F Note C	J • E • √2 Note D	K^2+L^2
		Gg CO_2 equivalent	Gg CO_2 equivalent	%	%	%		%	%	%	%	%
3 AFOLU												
3.B.1.a Forest Land Remaining Forest Land												
net carbon stock change in biomass	CO2	-1540	-1551	10%	35%	36%	0.11029	0.264	1.155048	9.24%	16.33%	3.52%
3.B.2.a Cropland Remaining Cropland												
net carbon stock change in mineral soils	CO2	-535	-1113	10%	100%	100%	0.46843	0.0074	0.829029	0.74%	11.72%	1.38%
net carbon stock change in organic soils	CO2	1813	1324	20%	90%	92%	0.55786	0.0264	0.986105	2.38%	27.89%	7.84%
3.B.3.a Grassland Remaining Grassland												
net carbon stock change in mineral soils	CO2	-1181	2907	0%	100%	100%	3.16390	0.0964	2.165308	9.64%	0.00%	0.93%
net carbon stock change in organic soils	CO2	100	67	30%	90%	95%	0.00151	0.0019	0.049906	0.17%	2.12%	0.05%
3.B.4.ai Peatlands Remaining Peatlands	CO2	0	0	0%	0%	0%	0.00000	0	0.000000	0.00%	0.00%	0.00%
3.B.4.ai Peatlands Remaining Peatlands	CH4	0	0	0%	0%	0%	0.00000	0	0.000000	0.00%	0.00%	0.00%
3.C.1.a Biomass Burning in Forest Lands	CO2	0	0	0%	0%	0%	0.00000	0	0.000000	0.00%	0.00%	0.00%
3.C.1.a Biomass Burning in Forest Lands	CH4	0	0	0%	0%	0%	0.00000	0	0.000000	0.00%	0.00%	0.00%
3.C.1.a Biomass Burning in Forest Lands	N2O	0	0	0%	0%	0%	0.00000	0	0.000000	0.00%	0.00%	0.00%
3.C.2 Liming	CO2	0	0	0%	0%	0%	0.00000	0	0.000000	0.00%	0.00%	0.00%
3.C.4 Direct N2O Emissions from Managed Soils: Agricultural Soils	N2O	0	0	0%	0%	0%	0.00000	0	0.000000	0.00%	0.00%	0.00%
3.C.4 Direct N2O Emissions from Managed Soils: N Fertilizers Application, Forest Land	N2O	0	0	0%	0%	0%	0.00000	0	0.000000	0.00%	0.00%	0.00%
3.C.5 Indirect N2O Emissions from Managed Soils	N2O	0	0	0%	0%	0%	0.00000	0	0.000000	0.00%	0.00%	0.00%
Total		-1343	1634				4.31099					0.1371
					Percentage uncertainty in total inventory:		2.07629				Trend uncertainty:	0.3703

2.5.2 Agriculture

This section of the report details the estimations of emissions of CH_4, CO_2, and N_2O, for the following sub-sectors:

1. CH_4 emissions
   - Enteric fermentation of domestic livestock
   - Manure management from domestic livestock
   - Flooded rice fields

2. CO_2 emissions
   - Lime and Urea application

3. N_2O emissions
   - Direct and indirect emissions from manure management
   - Direct and indirect emissions from managed soils

2.20.1.1 Enteric Fermentation (**CH_4**)

Livestock emit CH_4as a result of enteric fermentation and both $CH_4$and N_2O emissions are produced from livestock manure management systems. Because of their large size, large populations and the nature of the ruminant digestive system, cattle can be an important source of CH_4 emissions.

CH_4emissions from enteric fermentation accounted for 60% of total CH_4 emissions in Jamaica's 1994 GHG inventory. The main sources of these emissions are dairy cows, other cattle, and sheep. The methods used to estimate CH_4 emissions from livestock required defining important livestock subcategories and determining annual populations.

Recent information was obtained from surveys done in the dairy industry in 2004 (Jennings, et al 2004) and the whole cattle industry in 2005 (Jennings and Duffus, 2005) These data were used along with information obtained from the Agricultural Census of 1996 to estimate and project Dairy and Other Cattle population data from 2000-05.

The small ruminant industry in Jamaica is made up primarily of goats, with only a very small percentage of sheep. The Goat Breeders Association and the Sheep Producers Association have fairly reasonable estimates of the populations of goats and sheep in Jamaica from their very intimate relationship with the producers. Data on annual populations of these categories were obtained from these associations.

The population of horses in Jamaica over the inventory period was obtained from the Statistical Department, Jamaica Racing Commission, while the population of mules and asses were extrapolated from the data in the 1996 Agricultural Census.

Swine populations were developed from extrapolations around the population obtained in the 2003 "Survey of pig farmers in Jamaica" which was conducted by the Ministry of Agriculture. This survey compared and discussed the pig survey done in the agricultural census of 1996 and helped in determining the estimates of the populations for the other years.

The livestock population information is given in Table 2.68. Data were not available to support the level of detail required for an enhanced characterization of these species. Therefore, Tier 1 emission factors were used to estimate CH_4 emissions from enteric fermentation.

Table 2.68: Total Population of the Major Livestock Categories in Jamaica (2000-05)

Livestock species	Total animal populations for the major livestock species 2000-2005.					
	2000	2001	2002	2003	2004	2005
Dairy Cows	19,699	19,458	19,226	18,990	18,510	17,300
Other Cattle	86,850	83,029	79,207	75,386	71,564	66,750
Sheep	6,000	6,000	6,000	6,000	6,000	6,000
Goats	300,000	330,000	363,000	400,000	425,000	450,000
Horses	18,348	18,551	18,834	19,123	19,327	19,546
Mules and Asses	10,092	9,890	9,688	9,486	9,285	9,083
Swine	107,621	118,725	129,829	141,656	160,071	178,487
Poultry broilers	8,685,786	9,336,441	9,442,712	10,614,481	10,865,984	11,433,414
Poultry layers	560,671	585,226	527931	536,116	510,781	380,601

NB: Poultry data collected for manure management purposes, not enteric fermentation

Annual estimations of CH_4 emissions from livestock enteric fermentation for the period 2000-05 are given in Table 2.69. These data indicate a gradual decline in CH_4 emission from enteric fermentation from 8.17 Gg in 2000 to 7.73 Gg in 2005. This decline is due to a large decline in dairy cows and cattle populations over these years, which was only partly offset by the increase in goat population. The decline in dairy cows and cattle populations is related to the effects of globalization which forced local milk production to compete with cheaper imported milk power.

In addition, the threat and scare of “mad cow disease” and other health concerns have caused a general downturn in the prominence of beef. Conversely, the goat population has increased owing to a sustained research effort in the industry, led by CARDI, which has seen the introduction of exotic breeds for the enhancement of the genetic pool in local herds, as well as improved housing and feeding using introduced forage species and by-product feeds. There was also an increase in the swine population but this did not have a marked effect on CH_4 emissions.

Table 2.69: Estimates of Methane Emissions from Enteric Fermentation in Jamaica (2000-05)

Livestock categories	*Annual methane emissions from enteric fermentation (Gg CH_4)*					
	2000	2001	2002	2003	2004	*2005*
Dairy cows	1.24	1.23	1.21	1.20	1.16	*1.09*
Other cattle	4.86	4.65	4.43	4.22	4.01	*3.74*
Sheep	0.03	0.03	0.03	0.03	0.03	*0.03*
Goats	1.50	1.65	1.82	2.00	2.13	2.25
Horses	0.33	0.33	0.34	0.35	0.35	*0.35*
Mules & asses	0.10	0.10	0.10	0.09	0.09	*0.09*
Swine	0.11	0.12	0.13	0.14	0.16	*0.18*
Total	*8.17*	*8.11*	*8.06*	*8.03*	*7.93*	*7.73*

Manure Management (CH_4)

CH_4emissions from manure management, although smaller than that from enteric fermentation, can be an important source in confined animal management conditions where manure is managed in liquid based systems. In Jamaica, although most of the poultry is managed in confined systems, the manure is not managed in liquid based systems. Manure is managed by stockpiling i.e., solid storage. Poultry population data were further differentiated into broiler and layer populations. This information was obtained from the Jamaica Livestock Association annual production data.

Estimations of CH_4 emissions from animal manure management are also measured from the data given in Table 2.68, but this is a relatively smaller source of CH_4 emissions, particularly as manures are not normally stored under anaerobic conditions in Jamaica. There are two management systems for manure management in Jamaica – dry lot and pasture. The manure management emissions estimates are based on numbers of livestock and the fractions that use the dry lot manure management system. Tier 1 emission factors and IPCC default factors were used.

Table 2.70 gives fractions of animals that use the dry lot manure management system and the annual estimates of CH_4 emissions from the dry lot manure management (Direct Emissions) for 2000-05. There was a gradual increase in this source of CH_4 emissions, from 0.645 Gg in 2000 to 0.848 Gg in 2005. This was as a consequence of increased swine and broiler poultry production.

Table 2.70: Fractions of Animals Using the Dry Lot Manure Management System (MMS) and Estimates of Direct Methane Emissions from Manure Management in Jamaica (2000-05)

Livestock categories	*Fraction Using Dry Lot MMS*	*Annual methane emissions from manure management (Gg X 10^{-3} CH_4)*					
		2000	2001	2002	2003	2004	*2005*
Dairy cows	0.5	39.4	38.9	38.5	38.0	37.0	*34.6*
Other cattle	0.4	86.9	83.0	79.2	75.4	71.6	*66.8*
Sheep	0.5	1.20	1.20	1.20	1.20	1.20	*1.20*
Goats	0.5	66.0	72.6	79.9	88.0	93.5	*99.0*
Horses	0.1	40.2	40.6	41.3	41.9	42.3	*42.8*
Mules & asses	0.1	12.1	11.9	11.6	11.4	11.1	*10.9*
Swine	0.6	215	237	260	283	320	*357*
Poultry (Broilers)	0.9	174	187	189	212	217	*229*
Poultry (Layers)	0.9	11.2	11.7	10.6	10.7	10.2	*7.61*
Total		*646*	*684*	*711*	*762*	*804*	*848*

Flood rice cultivation (CH_4)

Anaerobic decomposition of organic material in flooded rice fields produces CH_4, which escapes to the atmosphere primarily by transport through the rice plants. CH_4 emissions are estimated by multiplying daily emission factors by cultivation period of rice and annual harvested areas. Neither flooded nor upland rice is of any major importance in Jamaica.

The data bank of the Ministry of Agriculture and Lands records the total areas of rice harvested over the past six years. The mean acreage of rice harvested over 2000-05 was 11.5 ha, with 18 ha cultivated in 2000 and just 1 ha in 2005. Using the Tier 1 default emission factor and relevant scaling factors, the estimation of CH_4 emission from this activity indicated very negligible levels.

Lime and Urea application (CO_2)

Emissions of CO_2following the addition of liming materials and urea-containing fertilizer were estimated from the total amounts of lime and urea application made to soil in a calendar year. Most of the soils of Jamaica are limestone derived and do not require lime application. In discussions with the staff of the Rural Physical Division of the Ministry of Agriculture, it was estimated that about 10% of crop lands received limestone application of 1-2 tonnes/ha. Lydford Mining Co. supplies all the limestone used for soil liming in Jamaica. This company supplied the data on limestone used in agriculture over the period 2000-05.

Urea application was quite widespread on all crops. The best means of determining the amount used was by obtaining the annual imports from STATIN.

For both estimations of CO_2emissions, Tier 1 emission factors were used as no country specific emission factors are available. Also CO_2emissions from lime and urea application are not considered a key category in Jamaica. The estimates of CO_2emissions from Lime and Urea application are given in Table 2.71. They indicate no definite pattern over the assessment period.

Table 2.71: CO_2 emissions (Gg) From Lime and Urea Application to Agricultural Soils in Jamaica (2000-05)

Category	2000	2001	2002	2003	2004	2005
3C2 Liming	6.00	0.00	0.000	6.00	7.20	6.00
3C3 Urea Application	1.56	7.20	7.20	1.59	1.43	0.57

Direct and Indirect Emissions from Manure Management (N_2O)

Manure management in a defined organized system is virtually non-existent in Jamaica. Chicken litter, cow and goat manures are cleaned out of the pens and stock piled. A small percentage is collected for use in crop production either directly or after composting. N_2O emissions from manure management are therefore likely to be related mainly to that lost through stockpiling (solid storage).

The estimation of N_2Os emission from livestock is based on the number of animals in each category (Table 2.68) and the typical daily excretion rate. This total excretion is then fractionated into that which is in an organized management system, that which is stockpiled, put into compost etc and that which is directly applied to pastures by grazing animals. The fraction estimated to be stored manure management systems range from a low of 0.10 for mules and asses to a maximum of 0.90 for poultry. This estimate was made based on expert knowledge.

Direct emissions occur by means of nitrification and de-nitrification of N contained in manure primarily during storage. The emission of N_2O from manure during storage and treatment depends on the N and C content of the manure, and the duration of the storage and type of treatment. The estimation was carried out using a Tier 1 method using N_2O emission factors, default N excretion data and default manure management system data.

These estimates are shown in Table 2.72 and indicate an increase of approximately 45,000 kg of N_2O emissions from 2000-05. This increase was due to the increased population of goats, swine and broiler poultry over this period, although there were lowered populations of dairy cows, other cattle and layer poultry during the period.

Table 2.72: Estimates of Direct N_2O Emissions from Manure Management in Jamaica (2000-05)

Livestock categories	*Annual direct N_2O emissions from manure management (kg N_2O yr^{-1})*					
	2000	2001	2002	2003	2004	*2005*
Dairy cows	21,694	21,428	21,173	20,913	20,384	*19,052*
Other cattle	44,973	42,994	41,015	39,036	37,057	*34,565*
Sheep	1,691	1,691	1,691	1,691	1,691	*1,691*
Goat	87,223	95,945	105,540	116,297	123,566	*130,835*
Horses	3,650	3,690	3,747	3,804	3,845	*3,888*
Mules & asses	692	678	665	651	637	*623*
Swine	20,948	23,109	25,271	27,573	31,157	*34,742*
Poultry (Broilers)	4,439	4,771	4,826	5,425	5,553	*5,843*
Poultry (Layers)	427	446	402	408	389	*290*
Total	*185,737*	*194,755*	*204,329*	*215,799*	*224,280*	*231,528*

Indirect emissions result from volatile nitrogen losses that occur primarily in the forms of ammonia and NO3 gases. The fraction of excreted organic nitrogen that is mineralized to ammonia nitrogen during manure collection and storage depends primarily on time and, to a lesser degree, temperature. Simple forms of organic nitrogen such as urea (mammals) and uric acid (poultry) are rapidly mineralized to ammonia nitrogen, which is highly volatile and easily diffused into the surrounding air (Asman *et al.*, 1998; Monteny and Erisman, 1998). Nitrogen losses begin at the point of excretion in houses and other animal production areas (e.g., milk parlours) and continue through on-site management in storage and treatment systems (i.e., manure management systems).

Indirect emissions were calculated based on the amount of nitrogen excreted from each livestock category a default fraction for volatilized nitrogen from stockpiling and a default emission factor for N_2O emission from volatilization. The annual indirect N_2O emissions from manure management are given in Table 2.73. These data indicate a gradual increase in the indirect emissions from 45,064 kg N_2O in 2000 to 57,089 kg in 2005. This increase is again related to the increased population of goats, swine and broiler poultry.

Table 2.73: Estimates of Indirect N_2O Emissions (Gg) from Manure Management in Jamaica (2000-05)

Livestock categories	2000	2001	2002	2003	2004	2005
Dairy cows	0.039	0.039	0.038	0.038	0.037	0.035
Other cattle	0.087	0.083	0.079	0.075	0.072	0.067
Sheep	0.001	0.001	0.001	0.001	0.001	0.001
Goats	0.066	0.073	0.080	0.088	0.094	0.099
Horses	0.040	0.041	0.041	0.042	0.042	0.043
Mules & asses	0.012	0.012	0.012	0.011	0.011	0.011
Swine	0.215	0.237	0.260	0.283	0.320	0.357
Poultry (Broilers)	0.174	0.187	0.189	0.212	0.217	0.229
Poultry (Layers)	0.011	0.012	0.011	0.011	0.010	0.008
Total	**0.646**	**0.684**	**0.711**	**0.762**	**0.804**	**0.849**

Direct Emissions from Managed Soils (N_2O)

The data required for direct N_2O emissions from managed soils are:

- FSN - annual amount of synthetic fertilizer N applied to soils, kg N y-1
- FON - annual amount of animal manure, compost, sewage sludge and other organic N additions applied to soils, kg N y-1
- FCR - annual amount of N in crop residues (above-ground and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils, kg N y-1
- FSOM - annual amount of N in mineral soils that is mineralized, in association with loss of soil C from soil organic matter as a result of changes to land use or management, kg N y-1
- FOS - annual area of managed/drained organic soils, ha
- FPRP - annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N y^{-}

The FSN was estimated from the total amount of synthetic fertilizer consumed in Jamaica annually. Annual fertilizer consumption data were collected from official records of N-fertilizer imports which were obtained from STATIN Jamaica.

FON refers to the amount of organic N input applied to soils other than by grazing animals. This includes applied animal manure, sewage sludge applied to soil, compost applied to soils, as well as other organic amendments of importance. There are no data available except that generated from animal excretions of the amount of managed manure nitrogen available for application to managed soils or for feed, fuel, or construction purposes (NMMS_Avb).

The estimate of managed manure nitrogen available for application to managed soils or available for use in feed, fuel, or construction purposes is based on the following equation:

The number of head of livestock species, manure management system, and amount of N from bedding were estimated using expert judgment. The amount of managed manure N for livestock was obtained from default values for total N losses from manure management systems presented in the 2006 IPCC Guidelines. These default values include losses that occur from the point of excretion, including animal housing losses, manure storage losses, and losses from leaching and runoff at the manure storage system.

There is no data of on FAM being used for feed, fuel or construction in Jamaica; the total amount is assumed to have been applied to the soil.

FCR was estimated from crop yield statistics and default factors for above-/below ground residue: yield ratios and residue N contents. The Tier 1 approach was used. This estimation was only required for annual crops as perennials do not renew annually and therefore leave substantial crop residue every year. The yields from the annual crops were separated into the following categories:

- Non-N-fixing grain crops (e.g., corn, rice).
- N-fixing grains and pulses (e.g., cowpea, red peas, peanuts);
- Root and tuber crops (e.g., yam, sweet potato, cassava); and
- Forages including perennial grasses and grass/legume pastures.

Land-use change and a variety of management practices can have a significant impact on soil organic C storage. Organic C and N are intimately linked in soil organic matter. Where soil C is lost through oxidation as a result of land-use or management change, this loss will be accompanied by a simultaneous liberalization of N. C losses from land use changes were estimated by the Forestry Department. FSOM was therefore calculated by multiplying the C losses provided by the Forestry Department by a C: N ratio of 15:1.

The Rural Physical Planning Division of the MoA that there were some managed organic soils (FOS) in Westmoreland. This information was sought from RADA but was not recorded and was described as being small and negligible. For forest and grasslands, national data were available from the Forestry Services.

FPRP was determined by animal category using expert judgment.

Direct N_2O emissions from agricultural soils accounted for more than 98% of total N_2O emissions from agricultural activities in the last inventory. It is therefore a key category for N_2O emissions in Jamaica. There are, however, no documented country-specific emission factors so emissions were estimated using Tier 1 equations, default emission factors, and expert knowledge and opinions on other activity data.

Estimates of direct N_2O emissions from managed soils in Jamaica 2000-05 are given in Table 2.74. These data indicate a high emission of approximately 8.9 million kg N in 2001 to a low of 6.9 million kg in 2005. This estimation is correlated with the changes in emissions from crop residues, which was by far the highest source of emissions.

Table 2.74: Estimates of Direct N_2O Emissions from Managed Soils in Jamaica (2000-05)

Source of N application	Direct N_2O emissions from managed soils (kg N yr-1)					
	2000	2001	2002	2003	2004	2005
Synthetic fertilizer	77,589	46,362	63,861	75,996	70,881	45,290
Organic manure	54,378	57,223	59,170	63,276	65,263	67,191
Crop residue	6,829,095	7,658,002	6,593,248	7,352,099	6,058,929	5,555,086
Liberalization of OM from Land use change	0	0	0	0	0	0
Managed organic soils	2,688	2,688	2,688	2,688	2,688	2,688
Organic additions to grazed soils	1,132,279	1,154,352	1,174,898	1,208,159	1,226,549	1,238,847
Total	8,096,029	8,918,627	7,893,865	8,702,218	7,424,310	6,909,102

Indirect Emissions from Managed Soils (N_2O)

In addition to the direct emissions of N2O from managed soils that occur through a direct pathway (i.e., directly from the soils to which N is applied), emissions of N_2O also take place through two indirect pathways. The first of these pathways is the volatilization of N as NH3 and oxides of N (NOx), and the deposition of these gases and their products NH4+ and NO3- onto soils and the surface of lakes and other waters. The sources of N as NH3 and NOx are not confined to agricultural fertilizers and manures, but also include fossil fuel combustion, biomass burning, and processes in the chemical industry. Thus, these processes cause N_2O emissions in an exactly analogous way to those resulting from deposition of agriculturally derived NH3 and NOx, following the application of synthetic and organic N fertilizers and /or urine and dung deposition from grazing animals.

The second pathway is the leaching and runoff from land of N from synthetic and organic fertilizer additions, crop residues, liberalization of N associated with loss of soil C in mineral and drained/managed organic soils through land-use change or management practices, and urine and dung deposition from grazing animals. Some of the inorganic N in or on the soil, mainly in the NO3- form, may bypass biological retention mechanisms in the soil/vegetation system by transport in overland water flow (runoff) and/or flow through soil macro-pores or pipe drains.

Where NO3- is present in the soil in excess of biological demand, e.g., under cattle urine patches, the excess leaches through the soil profile. The nitrification and de-nitrification processes transform some of the NH4+ and NO3- to N_2O. This may take place in the groundwater below the land to which the N was applied, or in riparian zones receiving drain or runoff water, or in the ditches, streams, rivers and estuaries (and their sediments) into which the land drainage water eventually flows.

This estimation was concerned with the following N sources of indirect N_2O emissions from managed soils arising from agricultural inputs of N:

- Synthetic N fertilizers (FSN);
- Organic N applied as fertilizer (e.g., applied animal manure, compost, sewage sludge, rendering waste and other organic amendments) (FON);
- Urine and dung N deposited on pasture, range and paddock by grazing animals (FPRP);
- N in crop residues (above- and below-ground), including N-fixing crops and forage/pasture renewal returned to soils (FCR); and
- N liberalization associated with loss of soil organic matter resulting from change of land use or management on mineral soils (FSOM).

The fraction of the N sources, above, which are lost through volatilization and leaching were determined by category using expert judgment. Indirect N_2O emissions from agricultural soils similarly have available data. Emissions were therefore estimated using the Tier 1 equation with default emission and partitioning factors, and other available activity data.

Estimates of indirect N_2O emissions from managed soils in Jamaica for 2000-05 are given in Table 2.75. As would be expected, this followed the same trend as with direct emissions. In 2001, there was the highest indirect emission of 1.8 million kg N, while the lowest emission of 1.3 million kg N was in 2005.

Table 2.75: Estimates of indirect N_2O Emissions from Managed Soils in Jamaica (2000-05)

Source of N	Indirect N_2O Emissions from Managed Soils (kg N yr^{-1})					
	2000	2001	2002	2003	2004	2005
Deposition of N volatised from managed soils	34,030	31,982	34,644	37,366	37,675	35,837
N leaching /runoff from managed soils	1,583,558	1,764,246	1,529,640	1,704,809	1,413,618	1,295,306
Total	1,617,588	1,796,228	1,564,284	1,742,175	1,451,293	1,331,143

Uncertainty Analysis, Quality Assurance and Quality Control

Enteric fermentation: Data obtained for populations of important livestock categories over the inventory period varied widely in uncertainty levels as a result of the varying sources. For enteric fermentation, the more important populations are those of dairy cows, other cattle and goats. The dairy cows and other cattle data were obtained from recent surveys and the uncertainty associated with these populations is estimated at 5-10%. The goat population data are not recorded, but were obtained from discussions with members of the Goat Breeding Society. These data were therefore more subjective and are assigned an uncertainty of 10-15%. The emission factors were all default values from the 2006 IPCC Guidelines and have an uncertainty level of 30-50%.

Manure management: A wider range of livestock categories were involved than for enteric fermentation. The additional animal populations of major importance were swine and poultry. Swine data were obtained from a survey done in 2003 which was described as very reliable. It is therefore considered to have an uncertainty level of 5%. Poultry populations were derived from actual production records and were similarly considered to be very reliable, i.e., 5% uncertainty level. The emission factors were all default values from the 2006 IPCC Guidelines and had an uncertainty of 30%.

Urea and limestone applications: Data on urea and limestone applications were obtained from actual import records and company sales respectively. These are fairly reliable sources that would have an uncertainty level of no more than 5%. Tier 1 default emission factors were used in both instances; the uncertainty levels for these are 50%.

Manure management: The fractionation of total excretion into that which is in an organized management system and that which is directly applied to pasture by grazing animals was done by expert judgment. This was highly subjective and had an uncertainty level of 20-30%.

The estimates were carried out using the Tier 1 method and default N excretion data, default manure management system data, default fractions for volatilization and emission factor for N_2O emission from volatilization. The uncertainty levels for these default values are:

- Default N excretion data – Uncertainty level 50%
- Default manure management emission factor – Uncertainty factor of 2
- Emission factor for direct N_2O emission - Uncertainty factor of 2
- Default fractions for volatilization – Uncertainty factor of 2
- Emission factor for N_2O emission from volatilization
- Uncertainty range 0.002 - 0.05

Direct and indirect emissions of N_2O: The data for the estimation of direct and indirect emissions are quite varied in their uncertainty levels. This is mainly because the source of data varied in reliability except for that related to synthetic fertilizer application, which was determined from STATIN import records. Many of the other data depended on expert judgment.

In addition the fractionation and emission factors were default values taken from the 2006 IPCC Guidelines. The uncertainty levels for all the parameters used are given below in Table 2.76.

Table 2.76: Uncertainty Levels for Parameters Used In the Direct and Indirect Emissions of N_2O from Managed Soils in Jamaica

Parameters	Symbol	*Uncertainty level*
Synthetic N applied	Fsn	*5%*
Organic N applied	Fon	*20-30%*
Fraction of total annual nitrogen excretion for each livestock species/category *T* that is managed in manure management system *S*	M S(T,S)	*20-50%*
Amount of managed manure nitrogen for livestock category *T* that is lost in the manure management system	FracLossMS	*10-70%*
Amount of nitrogen from bedding	NbeddingMS	*50%*
N in crop residue	Fcr	*30-50%*
N from liberalization of C	Fsom	*5%*
N from drained organic soils	Fos	-
N from grazing animals deposit	Fprp	*20-30%*
Emission Factor for N_2O emissions from other N inputs	EF1	*0.003 – 0.03*
Emission Factor for N_2O emission from grazing animals deposits	EF3prp.cpp	*0.007 – 0.06*
Emission Factor for N_2O emission from grazing animals deposits	EF3prp.so	*0.003 – 0.03*
Fraction of Fsn that volatilises	$Frac_{GASF}$	*0.03 – 0.3*
Fraction of Fprp that volatilises	$Frac_{GASM}$	*0.05 – 0.5*
Emission Factor for N_2O emission from atmospheric deposition of N on soils and water surfaces	EF4	*0.002 – 0.05*
Fraction of all N added to soil that is lost through leaching and runoff	$Frac_{LEACH-(H)}$	*0.1 – 0.8*
Emission factor for N_2O emissions from N leaching and runoff	*EF5*	*0.0005 – 0.025*

2.6 WASTE SECTOR GHG EMISSIONS

The waste sector comprises:

a) Domestic and industrial wastewater
b) Solid waste disposal facilities
c) Open burning
d) Incineration (industrial and medical)
e) Biological treatment of solid waste

The 2006 IPCC Guidelines were used to calculate the GHG emissions which include CO_2, CH_4, and N_2O.

Methane Emissions from Domestic Wastewater

The Tier 2 methodology was used to calculate the CH_4 emissions from domestic wastewater treatment plants in Jamaica. Although the default emission factor was utilized, country specific activity data were used to calculate the average BOD5 in g per capita per year.

Population data for 2000-05 were obtained from STATIN. To calculate the fraction of the population in high-urban, low-urban and rural income groups (Table 2.77), population data were obtained from STATIN for 2001 (Population Census 2001 – Housing, Volume 4 Part A). This document also provided data for:

- Total dwellings in high-urban (Kingston, St. Andrew and St James), low-urban (other towns) and rural areas
- Average number of persons per dwelling (3.61 persons/dwelling)

This enabled the population in the high-urban, low-urban and rural income areas to be calculated (*Total dwellings x average persons per dwelling = population).*

Table 2.77: Population Data (2001)

	Total Dwellings	Population	Population Fraction
High urban (Kingston & St Andrew, Montego Bay)	192,130	693,589	0.2657
Low urban	186,707	674,012	0.2582
Rural	344,203	1,242,573	0.4760
Total	723,040	2,610,174	1.00

Source: STATIN

The average annual Biochemical Oxygen Demand (BOD5) data for domestic/commercial wastewater for 2000-05 obtained from the National Water Commission (NWC) and NEPA for 24 wastewater treatment plants were not complete. The 2001 data on the capacity of the wastewater treatment plants were obtained from the NWC website. However, data on the average population being served by the wastewater treatment plants were not provided for six (Claremont, Cornwall Courts HS, East Prospect WWTP, Ebony Vale, Eltham Park, College Green) out of 16 plants. Sparse data for the BOD [mg/l] were available to calculate an average BOD loading rate [g/yr] and average BOD5 [g/capita/day]. There was no plant where BOD results were available for every year and even for plants with results; only a few values were available. In those cases where there were two or more results available for the same year, an average BOD [mg/l] was estimated.

In calculating the total average annual BOD5 [g/capita/day] for 2000-05, BOD5 values of more than 100 mg/l and less than 0.1 mg/l were not taken into consideration as they were too different from the values obtained for the other plants and deemed outliers. The plants that were excluded were Boone Hall, with an average BOD5 of 0.09 mg/l, and Barbican Mews, with an average BOD5 of 491.48 mg/L.

The total average annual BOD5 was calculated to be 9.73 g/capita/day.

Neither the NEPA nor the National Water Commission Lab was able to provide any data on sludge removal. It was assumed that no sludge was removed, so a value of zero (0) was used for the fraction of Degradable Organic Component removed as sludge.

The sewage treatment facilities for Jamaica are predominantly aerobic systems. The data on the performance of the systems (degree of utilization (Tij) in high-urban, low-urban and rural areas) for 2002 was obtained from PIOJ and STATIN (Jamaica Survey of Living Conditions 2002, Table F3). The same data were used for all years 2000 to 2005. Default Methane Correction Factors (MCF) was used. Wastewater treatment plants in Jamaica fall into two main categories for which default MCF values were provided:

- 0.1 for untreated systems with high organic loadings or
- 0.3 for treated, not well managed systems.

Therefore, an average default MCF value of 0.2 was estimated. The default value of 0.6 kgCH4/kgBOD was used for the Maximum methane producing capacity (B0). The emission factor for domestic wastewater was calculated to be 0.12 kgCH4/kgBOD (MCF x default value B0) for 2000-05. There were no values for sludge production, so the emission factor for domestic sludge is zero for all the years. The estimated methane emissions for domestic wastewater are in Table 2.78.

Table 2.78: Estimated Methane Emissions from Domestic Wastewater Treatment Facilities in Jamaica (2000-05)

Year	Methane emissions [kg CH_4/yr]
2000	1,101,051
2001	1,107,600
2002	1,112,745
2003	1,117,720
2004	1,123,418
2005	1,128,733

<u>Methane Emissions from Industrial Wastewater</u>

The Tier 2 methodology was used to calculate the CH_4 emissions from industrial wastewater treatment plants in Jamaica. Default wastewater generation and corresponding chemical oxygen demand (COD) values for each industry were used, except for sugar refining where the wastewater generation value was calculated from industry data. Country specific activity data on production were used to calculate the Total Organically Degradable Material in Wastewater for each industry (TOW) in kg COD/year.

The total organically degradable material in wastewater (TOW) for the different industrial sectors was calculated using the 2006 IPCC Guidelines methodology. Data for the total industrial product (P) for industrial sectors for 2000-05 were obtained from PIAJ (Economic and Social Survey Jamaica, 2004 and 2006).

Based on the sparse data provided by the NEPA (Table 2.79), it was not possible to determine the amount of wastewater (W) generated and the COD for the different types of industries except in the case of the sugar industry. Default values from the 2006 IPCC Guidelines and the IPCC Good Practice

Guidance and Uncertainty Management in National Greenhouse Gas Inventories (GPGAUM) were used instead for most industries. However since actual data for wastewater generated per tonne of production was available for the sugar industry – a major industry which generates large quantities of industrial wastewater – this value was calculated using the 2003 sugar production of 16,798 tonnes from Bernard Lodge and the 2003 quantity of wastewater generated which was 560,000 m^3.

The production data was obtained from the Sugar Industry Institute 2005 Annual Report and the quantity of wastewater generated by Bernard Lodge in 2003 was obtained from the data collected for the Kingston Harbour Study[21] conducted in October 2004. The value calculated of $33m^3/t$ was noticeably higher than the suggested range of 4 to 18 m^3/t in the IPCC GPGAUM.

There are some important industries such as coffee and cocoa refining that generate significant quantities of wastewater, for which there were no values for wastewater generation (default or actual).

Table 2.79: Annual Production, Wastewater Generation and COD values for Primary Industries in Jamaica (2000-06)

	2006 IPCC Guidelines		Total industrial product [t/yr] (Economic and Social Survey, Jamaica 2004 & 2006)						
Industry Type	Wastewater Generation W [m^3/ton]	COD [kg/m3]	2000	2001	2002	2003	2004	2005	2006
Alcohol Refining	24	11	17,804	22,291	22,808	23,686	26,623	26,233	22,783
Beer & Malt	6.3	2.9	69,856	78,566	78,162	75,250	80,636	83,657	86,955
Coffee & Cocoa		9	18,321	15,733	18,120	15,976	18,234	9,447	12,985
Dairy Products	7	2.7	6,789	5,746	5,601	4,920	5,374	6,028	4,877
Fish Processing	13		4,320	5,000	13,233	12,256	13,696	14,068	21,087
Meat & Poultry	13	4.1	98,345	102,947	104,156	114,846	115,330	120,906	118,113
Sugar Refining	33	3.2	209,825	205,128	175,214	158,356	181,042	126,071	142,806
Vegetables, Fruits & Juices	20	5	450,530	490,296	431,579	491,473	414,790	391,708	467,802
Petroleum Refineries	0.6	1	934,820	929,175	1,132,232	813,143	675,645	437,698	1,033,055
Detergent	2.5		1,513	1,515	1,512	1,402	1,595	1,519	1,609
Vegetable Oil	20		12,304	13,966	14,715	17,949	17,506	16,693	21,122

[21] Institutional Strengthening for Enhanced Environmental Management of Kingston Harbour, Component B, Improving The Environmental Performance Of Industries Discharging To Kingston Harbour, Prepared for the National Environment and Planning Agency by Claude Davis & Associates

Data on sludge and the amount of methane recovered was unavailable. The total organic sludge from industrial sources and the amount of CH_4 recovered were therefore estimated to be zero.

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 the 2006 IPCC Guidelines was used. A default value of 0.25 for the maximum methane producing capacity (B0) was also used from the Guidelines. The emission factor for industrial wastewater was calculated to be 0.05 kgCH4/kgCOD (MCF x default value) for 2000-05.

The estimated CH_4 emissions from industrial wastewater facilities are shown in Table 2.80.

Table 2.80: Methane Emissions from Industrial Wastewater Treatment Plants in Jamaica (2000-05)

Year	Net methane emissions [kg CH_4/yr]
2000	3,955,901.90
2001	4,208,226.07
2002	3,772,327.16
2003	4,009,989.03
2004	3,787,637.79
2005	3,387,933.03

Nitrous Oxide Emissions From Wastewater

The 2006 IPCC Guidelines methodology was used. It addresses indirect N_2O emissions from wastewater treatment effluents that are discharged into aquatic environments. Data on per capita protein generated (kg/per person/yr) from the Food and Agriculture Organization website (FAOSTAT) were used, as well as population data from STATIN. The per capita protein generated consists of intake (consumption) multiplied by factors to account for the fraction of nitrogen in protein, additional non-consumed protein and for industrial protein discharged into the sewer system. The default value used for developing countries for non-consumed protein was 1.1 and the default value used for the contribution from industrial or commercial sources was 1.25 as suggested by the 2006 IPCC Guidelines.

Population data for 2000-05 was obtained from STATIN. Data on per capita protein available for consumption from 2001-03 were obtained from the FAOSTAT website. It was assumed that all protein available for consumption was actually consumed. An average value of 24.82 kg/person/year for 2001-03 was given and the same value was used for 2000, 2004 and 2005.

The following default values from the 2006 IPCC Guidelines were used:

- fraction of Nitrogen in protein (FNPR) - 0.16 kg N/kg protein
- the non-consumed protein (FNON-CON) added to wastewater - 1.1 and
- for industrial and commercial co-discharged protein (FIND-COM) - 1.25
- the emission factor (EFEFFLUENT) -0.005 kg N2O-N/kg sewage-N produced.

The estimated N_2O emissions from wastewater for 2000-05 are shown in Table 2.81.

Table 2.81: Estimated Nitrous Oxide Emissions from Wastewater in Jamaica (2000-05)

Years	N_2O Emissions [kg N_2O/yr]
2000	111,093
2001	111,754
2002	112,273
2003	112,775
2004	113,350
2005	113,886

Biological Treatment of Solid Waste:

The use of biodigesters to process solid waste and recover energy for use is being promoted by the Scientific Research Council (SRC) (Jamaica) and has become a more significant source of potential CH_4 emissions in Jamaica since 2000.

Biodigesters produce biogas, an alternative fuel source. They are appropriate technologies that take advantage of the energy that is naturally present in animal waste and kitchen trash. As these wastes break down, whether in the ground, a compost heap, landfill, or biodigester, they release CH_4. In contrast to the other waste storage and disposal methods mentioned, a biodigester traps the $CH_4$and stores it for heating, cooking, or lighting. In this way, biodigesters can provide a sustainable substitute for the propane, kerosene, and firewood that many rural families in developing countries use to serve these needs.

For those families that have to buy their fuel, a biodigester can save them significant sums of money every year. For those that cut trees down for firewood, a biodigester will save them time and help to prevent the deforestation that is becoming prevalent in places where large numbers of people still gather their own firewood.

The Tier 1 methodology was used to determine the CH_4emissions 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 together with national data on the amount of CH_4generated from these facilities.

The SRC indicated that no CH_4generated from biologically treated solid waste was released, so estimated emissions were based on percentage loss from unexpected events or leakages suggested by the 2006 IPCC Guidelines.

Information from the Scientific Research Council indicated that about 75 % of CH_4generated from all biologically treated solid waste was used and the remainder was burnt off/ flared. However, the 2006 IPCC Guidelines 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_4generated by the biodigesters by between 0-10 percent. It was therefore assumed in this case that the leakages would be minimal and a value of 5 percent was used.

Data for the CH_4gas flow rate [m^3/day] was provided by the Scientific Research Council for the 2000-05. Using the density of CH_4 (0.717 kg/m^3), the CH_4emissions were calculated. The estimated $CH_4$and N_2O emissions from biodigesters for 2000-05 are negligible, as shown in Table 2.82.

Table 2.82: Estimated Methane and Nitrous Oxide Emissions from Biodigesters in Jamaica (2000-05)

Year	Methane Emissions	N_2O Emissions
	[Gg CH_4/yr]	[Gg N_2O/yr]
2000	2.22E-05	Negligible
2001	2.36E-05	Negligible
2002	2.39E-05	Negligible
2003	2.54E-05	Negligible
2004	3.17E-05	Negligible
2005	3.39E-05	Negligible

Solid Waste Disposal

The Tier 2 methodology was used to calculate the CH_4emissions from solid waste disposal sites in Jamaica. Default parameters and country specific activity data on current and historical solid waste disposal were utilized in the other calculations. Since there was not enough activity data available for 1950-89, the CH_4emissions were only calculated for 1990-05.

Population data were obtained from STATIN. Exact values were provided for 2000-05 (STATIN website), while the population was estimated for 1990-95 based on data for 1991 and an annual growth rate of 0.86 (Statistical Year Book 1999). Population data for 1996-99 were obtained from the report on the National Solid Waste Management Programme by Keir Corporation dated June 2000.

Information on Jamaica's per capita generation rate for Municipal Solid Waste (MSW) in 1994 was estimated to be 0.75 kg/capita/day and the fraction of municipal solid waste disposed to solid waste disposal sites was estimated to be 67%. These data were used for 1990-99. (Data obtained from the Norconsult Comprehensive Solid Waste Management Study National Waste Management Plan Volume 1 Summary Report April 1997 and supported by independent calculations based on 1994 population estimates and the estimated municipal solid waste generation rate). Jamaica's per capita generation rate for Municipal Solid Waste (MSW) for 2000-05 was estimated to be 1 kg/capita/day and the fraction of MSW disposed to solid waste disposal sites was estimated to be 75%. This is based on information provided by the National Solid Waste Management Authority (NSWMA) for Riverton in 2000.

Data for the quantity of waste disposed of at different sites was only complete for 2005. For 2000-04, the data were incomplete and for 2002 not available.

The NSWMA provided descriptions of the solid waste disposal sites that are currently in operation. For those that are now closed, reference was made to the GHG Inventory for 1990-94 for the description of the waste disposal sites. At the time the 1994 GHG Inventory was prepared, there was no information on the disposal site called Myersville. However since it is similar to the nearby located and similarly operated disposal site "Friendship" the description was set as unmanaged and shallow (data obtained from NSWMA).

With this information, the percentage of waste going to the different disposal sites and the Methane Correction Factors (MCF) were calculated. Only data for the total quantity of waste collected were available. Therefore, the same MCF was estimated for domestic and industrial waste.

Data for the waste streams and composition of domestic waste were available for Riverton in 2000 and 2006. The values for 2000 were also used for 2001-03, while the values for 2006 were used for 2004-05. The waste streams for plastics, metal/tin, glass and hazardous waste were combined into the fraction "plastics and other r inert materials" (NSWMA data).

Data for the stream and composition of domestic waste in 1996 were obtained from Jamaica SWM Study, Volume II: National Waste Management Plan and the same values were used for 1990-99.

Data on industrial waste generation was obtained from the June 2000 report on the National Solid Waste Management Programme by Keir Corporation (Table 2.83). The rate of industrial waste generation was calculated using the quantity of waste generated in 1999 and dividing it by the GDP for 1999. This rate of industrial waste generation was applied to 1990-98 and 2004-05. GDP data for 1990-05 was available in UN Statistics (http://unstats.un.org/unsd/snaama/selectionbasicFast.asp). The exchange rate used to convert J$ to US$ was J$67: US$1.

Table 2.83: Total Industrial Waste (tonnes/yr) in Jamaica (1999-03)

Year	1999	2000	2001	2002	2003
Industrial Waste (tonne)	222,226	224,431	226,661	228,919	231,184

CH_4 emissions from domestic and industrial solid waste disposal facilities for 1991-05 are reflected in Table 2.84.

Table 2.84: Estimated Methane Emissions from Municipal and Industrial Solid Waste Disposal Sites in Jamaica (1990-05)

Year	Methane (Gg)
1990	0
1991	2
1992	3
1993	5
1994	6
1995	7
1996	8
1997	10
1998	11
1999	12
2000	13
2001	18
2002	20
2003	22
2004	23
2005	24

Incineration

The Tier 1 methodology was used to estimate CH_4 and N_2O emissions.

Medical waste

Data on the quantity of waste incinerated were estimated in the case of medical waste based on data provided by some industries with incinerators for the period under review. Data from 1999 for the number of beds in hospitals and the amount of medical waste generated were obtained from the Ministry of Health (Quantification of Infectious Waste and Sizing of Incinerators for Selected Ministry of Health Institutions, 1999). These data were used to calculate the annual rate of waste generated per bed. Updated information on the number of beds in the hospitals Kingston Public Hospital, Victoria Jubilee Maternity, Bustamante Hospital for Children (BHC), Spanish Town Hospital and Princess Margaret Hospital in 2001 was obtained from the Ministry of Health website (http://www.moh.gov.jm/), which allowed the calculation of the amount of medical waste generated at each hospital for 2000 and 2001 using the generation rate from the 1999 study. This average figure of 93.5 kg/bed/year was used to calculate the quantity of waste generated for other hospitals for 2000 and 2001.

Data from 2002 for the number of beds and the amount of waste generated in the Kingston Public Hospital, May Pen Hospital, Mandeville Hospital, Montego Bay Type V Health Centre and St. Ann's Bay Hospital were obtained from the draft report on "Clinical Waste Management in Jamaica" by Scott Crossett and were used to calculate the amount of waste/bed/year for 2002. Missing data were replaced with those for 2001. The 2002 data were used for 2003 and 2004 with the exception of the University Hospital of the West Indies (UHWI). The number of beds and the amount of waste for UHWI were available from the EIA report "Environmental Impact Assessment for the Installation of a New Incinerator at the University Hospital of the West Indies, 2004". The 2004 values were assumed to be the same in 2005.

The default values for the emission factors for CH_4 and N_2O from the 2006 IPCC Guidelines were used (60 kg CH4/Gg waste and 100 kg N2O/Gg waste respectively).

Industrial Waste from Private Incinerators

The Norman Manley International Airport caters to over 1.7 million passengers and handles over 70 percent (16 million kilogram) of the island's air freight. The Airport business network is comprised of over 70 companies and government agencies, with over 3,500 persons directly employed at the Airport. The Airport Operator, NMIA AIRPORTS LIMITED, (since 2003) is a wholly-owned subsidiary of Airports Authority of Jamaica (AAJ); a statutory agency. The Airport is operated under a 30-year Concession Agreement with AAJ, and is held to specific performance targets.

The airport generates significant quantities of local and international waste. It is a Ministry of Health requirement for the international waste to be segregated and incinerated rather than being commingled with local waste and disposed of at the municipal disposal site. The incinerator at the airport has been in operation since October 2004, where an estimated 10.48 tons of waste per day is burned[22]. These are estimates since no facilities are available to weigh the waste.

The LASCO Group of Companies (Jamaica) comprises several businesses involved in manufacturing, packaging and distribution of high quality, nutritious and affordable products such as soy beverages, cereals, canned foods, household, personal care, pharmaceuticals and veterinary products. In addition LASCO offers financial and remittance services. An estimate of waste material generated at Lasco's Whitemarl warehousing and distribution facility, between 2000 and 2005 was based on actual figures for items prepared by the Quality Control Department for dumping in 2006 (Table 2.85).

Table 2.85: Quantity of Waste Incinerated Annually at Lasco's Whitemarl Facility (2000-05)

Year	Quantity of Waste Incinerated (kg)
2000	2000
2001	3000
2002	3000
2003	4000
2004	5000
2005	6000

Other Sites

No data were available for the following incinerators which were included on NEPA's list of those receiving permits since January 1997, when the permit and license system came into effect:

- Bosung Engineering and Construction Company Limited,
- Ministry of Agriculture at Plumb Point (Palisadoes)
- Health Corporation Limited
- National Supply Company Limited, Constant Spring Road
- The incinerator at Alpart, Nain, St. Elizabeth (which was never constructed).

The default emission factor from the IPCC 2006 Guidelines used to calculate CH_4 emissions (60 kg CH4/Gg waste). It was assumed that the type of incineration was batch type incineration – stoker. The default emission factor value used to calculate the N_2O emissions was 100 kg N2O/Gg waste for all types of industrial incineration. To calculate the CO_2 emissions, default values were obtained from the 2006 IPCC Guidelines for the relevant waste streams.

The estimated $CH_4$and N_2O emissions from incinerators for 2000-05 were negligible, as shown in Table 2.86. The estimated CO_2 emissions from medical and industrial waste incinerators for 2000-05 are shown in the Table 2.87.

[22] Environmental Audit of the Norman Manley International Airport, March 2000 by Donovan Rose & Associates and TEMN for the AAJ and the IDB

Table 2.86: Estimated Methane and Nitrous Oxide Emissions from Incineration in Jamaica (2000-05)

Year	Methane Emissions	N_2O Emissions
	[Gg CH_4/yr]	[Gg N_2O/yr]
2000	1.81E-05	3.01E-05
2001	1.81E-05	3.02E-05
2002	2.85E-05	4.75E-05
2003	2.85E-05	4.76E-05
2004	0.000269	0.000449
2005	0.000270	0.000449

Table 2.87: Estimated Carbon Dioxide Emissions from Incineration in Jamaica (2000-05)

Year	Type of Industrial waste	Fossil CO_2 emissions [GgCO_2]
2000	**Medical**	0.263
	Industrial	0.0033
	TOTAL	**0.267**
2001	**Medical**	0.263
	Industrial	0.00495
	TOTAL	**0.268**
2002	**Medical**	0.415
	Industrial	0.0066
	TOTAL	**0.421**
2003	**Medical**	0.415
	Industrial	0.0066
	TOTAL	**0.422**
2004	**Medical**	0.581
	Industrial	6.32
	TOTAL	**6.90**
2005	**Medical**	0.581
	Industrial	6.32
	TOTAL	**6.90**

Open Burning Of Waste

The Tier 2 methodology was used to estimate the CH_4 and N_2O emissions from open burning of waste. Country specific data on the quantity of open burned MSW was used together with default emission factors from the 2006 IPCC Guidelines.

The 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 emission factors from the 2006 IPCC Guidelines.

Population data for2000-05 were obtained from STATIN website and the proportion of waste open-burned in 2001 was obtained from Population Census 2001 Jamaica, Vol. 4 Part A, Housing. Of the total 748,326 households in Jamaica in 2001, 321,945 or 43% (Pfrac) reportedly burned their waste. This percentage was applied to all the other years in the inventory period, 2000, 2002-2005 in the absence of year specific data.

Per capita waste generation (MSWp) for Jamaica is 1 kg/per person per day. The 2006 IPCC Guidelines suggest that if all waste is burned without leaving a residue, the fraction of waste burned relative to the amount of waste treated (Bfrac) waste should be 1. In this case, it was estimated to be 0.8 as nearly all the waste is burned with a small amount of ash residue. It was also assumed that burning took place twice per week. All the foregoing data were used to estimate the total amount of municipal solid waste burned (MSWB).

MSWB was then used to calculate the CH_4 emissions by multiplying by a CH_4 emission factor of 6500g/t MSW wet weight (or 6500 kg/Gg) as suggested in the 2006 IPCC Guidelines. Similarly MSWB was multiplied by a N_2O emission factor of 150 g/t of MSW (or 150 kg/Gg) as indicated in IPCC Guidelines.

The waste composition data provided by the NSWMA was applied to the total amount of municipal solid waste burned to calculate the amount of each waste stream burned.

To calculate the CO_2emissions, dry matter content dm, fraction of carbon in dry matter and fraction of fossil carbon in Total carbon were all obtained from the 2006 IPCC Guidelines for the relevant waste streams. The default value for oxidation factor of 58 for open burning of MSW was used.

TheCO_2, N_2O and CH_4 emissions from open burning estimated for 2000-05 are shown in Table 2.89.

Table 2.89: Estimated Carbon Dioxide, Nitrous Oxide & Methane Emissions from Open Burning in Jamaica (2000-05)

Year	Fossil CO_2 emissions [$GgCO_2$]	N_2O emissions (GgN_2O)	Methane emissions ($GgCH_4$)
2000	36.1	0.01	0.60
2001	36.3	0.01	0.61
2002	36.5	0.01	0.61
2003	36.6	0.01	0.61
2004	36.8	0.01	0.61
2005	37.0	0.01	0.62

Summary of results

Tables 2.90 to 2.93 present a summary of the total greenhouse gas emissions from the waste sector.

Table 2.90: Total Carbon Dioxide Emissions (Gg) from the Waste Sector in Jamaica (2000-05)

Category	Year					
	2000	**2001**	**2002**	**2003**	**2004**	**2005**
Incineration (clinical and industrial	0.27	0.27	0.42	0.42	6.9	6.9
Open Burning of waste	36.1	36.3	36.5	36.6	36.8	37.0
Total	**36.3**	**36.6**	**36.9**	**37.0**	**43.7**	**43.9**

Table 2.91: Total Methane Emissions (Gg) from the Waste Sector in Jamaica (2000-05)

Category	Year					
	2000	**2001**	**2002**	**2003**	**2004**	**2005**
Domestic Waste Water	11.0	11.1	11.1	11.2	11.2	11.3
Industrial Waste Water	3.96	4.21	3.77	4.01	3.79	3.39
Biological Treatment of Solid Waste	neg	neg	neg	neg	neg	neg
Solid Waste Disposal	13	18	20	22	23	24
Incineration (clinical and Industrial	neg	neg	neg	neg	neg	neg
Open Burning of waste	0.6	0.61	0.61	0.61	0.61	0.62
Total	**28.6**	**33.9**	**35.5**	**37.8**	**38.6**	**39.3**

neg – negligible

Table 2.92: Total Nitrous Oxide Emissions (Gg) from the Waste Sector in Jamaica (2000-05)

Category	Year					
	2000	2001	2002	2003	2004	2005
Domestic Waste Water	0.11	0.11	0.11	0.11	0.11	0.11
Incineration (clinical and industrial)	neg	neg	neg	neg	neg	neg
Open Burning of waste	0.01	0.01	0.01	0.01	0.01	0.01
Total	0.12	0.12	0.12	0.12	0.12	0.12

neg – negligible

Uncertainties, Quality Analysis and Quality Control

Domestic waste water (CH_4): The average annual BOD5 data for domestic/commercial wastewater for 2000-05 obtained from the National Water Commission and the NEPA were not complete. No plant had data for every year and even within the year the plants were sampled, the data were sparse with only one or two values being available. Also where multiple values were available for a given treatment plant, the values often varied widely. The design capacities of the treatment plant had to be used, rather than the actual annual average flow rate.

Population data for the areas served by each treatment plant were only available for some plants (62.5% or 10 out of 16) for 2001. The missing data may affect the calculated value of 9.25 g BOD/capita/day. Even with the missing data, the calculated value for BOD/capita/day was believed to be more accurate than the estimated value of 40 g BOD/person/day for Asia, Middle East and Latin America from Table 6.4 in the 2006 IPCC Guidelines. Calculations on the population and fraction of population income group for 2000 and 2002-05 were done based on data from STATIN ("Population Census 2001 – Housing") for 2001.

Data for the population fraction for the other years were based on data for 2001 in the absence of year-specific data. Data for the degree of utilization of type of treatment system (sewered, not sewered, pit latrines) for 2002 were obtained from the 2002 Jamaica Survey of Living Conditions. The same data were used for 2000-05, even though there was a small increase in the use of unsewered water closets and a corresponding decline in the use of pit latrines based on the 2004 Jamaica Survey of Living Conditions. It was not possible to utilize the 2004 data however as, unlike the 2002 data, it did not have the urban to rural disaggregation.

Since no country-specific data were available for the emission factors for domestic wastewater, estimates were based on default emission factor values provided by the 2006 IPCC Guidelines. Using the default values, together with expert judgment, the percentage uncertainty in the CH_4 emission estimations were calculated and are presented in the Table 2.93.

Table 2.93: Percentage Uncertainty in Methane Emission Estimations for Domestic Waste Water Facilities

Parameter	Uncertainty %	Remarks
Emission Factor		
Maximum CH_4 producing capacity (B_o)	30	
Fraction treated anaerobically (MCF)	40	Mixture of Untreated systems and latrines and Lagoons, poorly managed treatment plants
Activity Data		
Human Population (P)	5	
BOD per person	40	
Fraction of population income group (U)	15	
Degree of utilisation of treatment/discharge pathway or system for each income group (T_{ij})	50	
Correction factor for additional industrial BOD discharged into sewers	20	
TOTAL	**200**	

Industrial waste water (CH_4): Data for the total industrial product (P) for 2000-05 for some industrial sectors were provided by PIAJ (Economic and Social Survey Jamaica 2004 and 2006). Since data for wastewater generated (W) and the chemical oxygen demand (COD) were not available, default values from the IPCC Guidelines were used. Data were not available for all sectors.

Some of the critical industrial sectors for which there was no data include:

- Coffee and cocoa industry, fish processing, detergent production and sugar refining – no IPCC values for the rate of generation of wastewater for these critical sectors which are known to produce significant qualities of wastewater;
- Fish processing, vegetable oil production, detergent production – no IPCC COD values.

Actual data for wastewater generated per tonne of production was available for the sugar industry – a major industry which generates large quantities of industrial wastewater. This value was calculated using the 2003 sugar production from Bernard Lodge and the 2003 quantity of wastewater generated. The production data was obtained from the Sugar Industry Institute 2005 Annual Report and the quantity of wastewater generated by Bernard Lodge in 2003 was obtained from the data collected for the Kingston Harbour Study[23] conducted in October 2004. The calculated value of 33 m^3/t was noticeably higher than the suggested range of 4-18 m^3/t in the IPCC GPGAUM.

[23] Institutional Strengthening for Enhanced Environmental Management of Kingston Harbour, Component B, Improving The Environmental Performance Of Industries Discharging To Kingston Harbour, Prepared for the National Environment and Planning Agency by Claude Davis & Associates

Since the wastewater generation rate per tonne of production was only calculated from one sugar factory and used as representative for all sugar factories, there could be some error in this figure.

Information for the maximum CH_4 producing capacity (B0) and CH_4correction factor was not available and default values from the 2006 IPCC Guidelines had to be used. Using the default values, together with expert judgment, the percentage uncertainty in the CH_4 emission estimations were calculated and are presented in Table 2.94.

Table 2.94: Percentage Uncertainty in Methane Emission Estimations from Industrial Wastewater Facilities

Parameter	Uncertainty %
Emission Factor	
Maximum CH_4 producing capacity (B_0)	30
Fraction treated anaerobically (MCF)	40
Activity Data	
Industrial production (P)	25
Wastewater/unit production (W)	40
COD/unit wastewater	
TOTAL	135

<u>Waste water (N_2O):</u> The data from the FAO on the amount of protein available for consumption should be reliable. However, per capita consumption of protein data were only available for 2001-03, so the same value was used for 2000, 2004 and 2005. Using the default values provided in the 2006 IPCC Guidelines, together with expert judgment, the percentage uncertainty in the CH_4 emission estimations was calculated and is presented in the Table 2.95.

Table 2.95: Percentage Uncertainty in Nitrous Oxide Emissions from Waste Water

Parameter	Uncertainty %
Emission Factor	
$EF_{EFFLUENT}$ (kgN_2O-N/kg-N)	30
EF_{PLANTS} (gN_2O/person/year)	40
Activity Data	
Human Population (P)	5
Protein	10
Fraction of nitrogen in protein (F_{NPR}) (kgN/kg protein)	6
Degree of utilisation of large WWT plants (T_{plant})	20
Factor to adjust for non-consumed protein ($F_{NON-CON}$)	30
Factor to allow for co-discharge of industrial nitrogen into sewers ($F_{IND-CON}$)	20
TOTAL	161

Biological treatment of solid waste: Uncertainties for activity data related to biologically treated waste was done using information from the 2006 IPCC Guidelines. Uncertainties related to the emission factors were calculated using the ranges provided in the 2006 IPCC Guidelines.

The data from the Scientific Research Council on the CH_4gas flow rate is expected to be reliable and a +10% error was assumed. The CH_4recovery (R) uncertainty was obtained from the 2006 IPCC Guidelines which suggested a % uncertainty for metered CH_4recovery or flaring systems of +10. The % uncertainty for the CH_4emission factor for a value of 2 within a range of 0 to 20 was calculated to be -100% to +900%. This information was obtained from the 2006 IPCC Guidelines. The overall uncertainty was therefore calculated to be -120% to +920% (Table 2.96).

N_2O emissions are assumed to be negligible and an uncertainty analysis was therefore not done.

Table 2.96: Percentage Uncertainty for Estimated Methane Emissions From Biodigesters

Parameter	Uncertainty %
Emission Factor	
Emission factor	-100 to +900
Activity Data	
Methane recovery (R)	10
Methane gas flow rate	10
TOTAL	-120 to +920

Solid waste disposal: Population data were estimated for 1990-95 based on data for 1991 and an annual growth rate of 0.86. Data on Jamaica's per capita generation rate and the fraction of municipal solid waste disposed to solid waste disposal sites for 1994 was used for 1990-99. For 2000-05, data from 2000 was extrapolated using the annual growth rate. However, the actual data may vary from the calculated data.

Data for the quantity of waste disposed of at different sites was only complete for 2005. For 2000-04, the data were incomplete and for 2002 not available. Therefore, calculations on the percentages of waste going to the different disposal sites and the Methane Correction Factors (MCF) may have some error.

Data for the waste streams and composition of domestic waste was available for 1996, 2000 and 2006. For 1990-05, data were extracted from this information, but the actual values might be different. Estimates of uncertainties were calculated based on the 2006 IPCC Guidelines (Table 2.97).

Table 2.97: Percentage Uncertainty for Methane Emissions from Solid Waste Disposal Sites

Activity data and emission factors	Uncertainty %	Remarks
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
Fraction of CH_4 in generated landfill gas (F)	5	IPCC default values used
Half life ($t_{½}$)	30	IPCC default values used
TOTAL	**225**	

Incineration: For medical waste, it was assumed that each hospital bed had 100% occupancy throughout the year, although it is likely that occupancy levels varied. Also it was assumed that all waste generated was incinerated. Data for the amount of medical waste and the number of beds in hospitals were not available for all hospitals in all years so there were some uncertainties in the estimates of the amounts of waste incinerated. There were also two medical facilities for which no information was available on the annual rate of generation of solid waste: the National Public Health Laboratory and the National Blood Bank.

Site-specific emission factors for CH_4 and for N_2O were not available and default values obtained from the 2006 IPCC Guidelines were used.

For industrial waste, data for the amount of waste burned at Norman Manley International Airport was based on estimates since no weighing facilities are 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. Also there are incinerators in operation throughout the country which existed prior to the NEPA permit and license system (introduced in January 1997) for which no data is available.

Table 2.98 provides information on the calculated uncertainties associated with the estimation of emissions for CH_4, CO_2 and N_2O. There was insufficient information in the 2006 IPCC Guidelines to calculate the percentage uncertainty for CO_2 emissions.

Table 2.98: Percentage Uncertainty in Methane, Carbon Dioxide and Nitrous Oxide Estimations for Medical and Industrial/Private Sector Waste Incineration

Activity data and emission factors	Uncertainty %			Remarks
	CO_2	N_2O	CH_4	
Amount of solid waste incinerated	70	70	70	Some waste incineration data available
Fraction of carbon in dry matter	50	N/A	N/A	IPCC default values used
Fraction of Fossil Carbon on Total Carbon	100	N/A	N/A	IPCC default values used
Oxidation factor	20	N/A	N/A	IPCC default values used
Conversion factor	0	N/A	N/A	IPCC default values used
Methane Emission factor	N/A	N/A	100	IPCC default values used
Nitrous oxide emission factor	N/A	100	N/A	IPCC default values used
TOTAL	?	170	170	

Open burning of waste: The default value for the fraction of waste burned relative to the amount of waste treated (Bfrac) had to be used in the absence of country specific data. Data for the waste streams and composition of domestic waste were available for 2000 and 2006. The 2000 data were used for 2001-03 while the 2006 data were used for 2004-05.

Table 2.99 provides information on the calculated uncertainties associated with the estimation of emissions for CH_4, CO_2 and N_2O. There was insufficient information in the 2006 IPCC Guidelines to calculate the percentage uncertainty for CO_2emissions.

Table 2.99: Percentage Uncertainty in Methane, Carbon Dioxide and Nitrous Oxide Estimations for Incineration by Open Burning of Waste

Activity data and emission factors	Uncertainty %			Remarks
	CO_2	N_2O	CH_4	
Amount of solid waste incinerated	20	20	20	Some waste incineration data available
Fraction of carbon in dry matter	50	N/A	N/A	IPCC default values used
Fraction of Fossil Carbon on Total Carbon	100	N/A	N/A	IPCC default values used
Oxidation factor	20	N/A	N/A	IPCC default values used
Conversion factor	0	N/A	N/A	IPCC default values used
Methane Emission factor	N/A	N/A	100	IPCC default values used
Nitrous oxide emission factor	N/A	100	N/A	IPCC default values used
TOTAL	**?**	**120**	**120**	

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CHAPTER 3: PROGRAMMES CONTAINING MEASURES TO MITIGATE CLIMATE CHANGE

A mitigation assessment provides a national-level analysis of the potential costs and impacts of various technologies and practices that have the capacity to reduce greenhouse gas (GHG) emissions. The assessment presented here was initiated in March 2009. The scope of the assessment covers projections of GHGs for 2009-35 and uses historical data for 2000 (the base year) to 2008 in order to calibrate, where appropriate, the bases for the projections. Three groups of scenarios were developed to project emissions – a Reference Scenario and two other scenarios characterised primarily by different rates of growth of the gross domestic product (GDP).

The assessment draws upon the overarching strategic direction that will guide Jamaica's development to 2030, as articulated in *Vision 2030 Jamaica: National Development Plan*. The Plan outlines four national goals, 15 national outcomes, and over 50 national strategies to achieve them. The national strategies will be implemented through sector level programmes, plans and activities for the social, governance, economic, and environmental goals of Vision 2030. The Plan will be supported by seven three-year, medium-term socioeconomic policy framework (MTF) documents. MTF 2009-12 is the first such document, which includes one outcome on energy efficiency and conservation. It is recognised that the 25-year period selected for this mitigation assessment goes five years beyond *Vision 2030*.

Although the assessment focuses primarily on energy related emissions, non-energy sector activities (agriculture, forestry, waste, and non-energy emissions) are also included. As noted in Chapter 2 (GHG Inventory), carbon dioxide (CO_2) emissions in the energy sector have been trending up over 2000-05 – increasing from 9,531 Gigagrams (Gg) in 2000 to 13,956 Gg in 2005. The energy sector accounted for nearly 86 per cent of the 2000 CO_2emissions.

The mitigation assessment is presented in four sections. Section 1 provides background information on characteristics most relevant to Jamaica's mitigation analysis (e.g., resources, common macroeconomic data). The approach (model description and scenarios) and the constraints in developing the mitigation assessment are described in Section 2. Section 3 presents the results, while mitigation options, policy implications, capacity building needs, and recommendations are presented in Section 4.

3.1. Background Information

As measured by the Human Development Index[1] (HDI), Jamaica is considered to be a medium level developing country, with an HDI score of 0.736, ranking 101st out of 177 countries in 2008. The HDI combines measures of life expectancy, literacy, school enrolment and per capita GDP into a single index to measure relative human development among nations. This index value reflects that Jamaica is characterized by weak economic development, as evidenced by low GDP growth rates, high debt load, high unemployment, weak export performance and energy dependence but relatively strong social indicators including a high life expectancy, high primary and secondary enrolment rates, high literacy rates, low birth rates, as well as high access to electricity and piped water (see Table 3.1).

Table 3.1: Select Socio-Economic Indicators for Jamaica (2000-08)

INDICATORS	2000	2005	2006	2007	2008
Real GDP Growth (%)	0.9	1.0	2.7	1.4	-0.6
Debt: GDP Ratio	88.7	119.1	117.5	111.4	
Average Annual Unemployment Rate (%)	15.5	11.2	10.3	9.9	10.6
Average Annual Exchange Rate (J$ = US$ 1)	43.08	62.50	65.88	69.06	72.92
Inflation (%)	6.1	12.6	5.7	16.8	16.8
Population ('000)	2,597,100	2,656,700	2,669,500	2,682,100	2,692,400
Population Growth Rate (%)	0.6	0.5	0.5	0.5	0.4
Life Expectancy at Birth (years)	72.2	73.3	73.3	72.4	
Adult Literacy (% of ages 15 and older)	79.9	79.9	85.5	86.0	
Gross Primary Enrolment ('000)	325.3	326.4	318.7	310	
% Population below Poverty Line	18.9	14.8	14.3	9.9	
Access to Piped Water	66.6	n/a	67.8	70.2	
Access to Electricity			92	92	92

Source: Adapted from Vision 2030 Jamaica: National Development Plan.
Other sources: Bank of Jamaica: http://www.boj.org.jm/exchange_rates_annual.php
STATIN: http://www.statinja.gov.jm/population.aspx

In 2008, Jamaica's GDP per capita was US$5,345 (98th among 210 nations and territories of the world). Notwithstanding this, Jamaica ranked 54th out of 147 countries in the 2008 Environmental Performance Index (EPI), outperforming many developed countries and being among the leaders in the Caribbean with respect to environmental protection and sustainability[2].

As indicated in Table 3.1, between 2000 and 2008, the population rose from 2,597,100 to 2,692,400 although the growth rate declined from 0.6 percent to 0.4 percent[3]. The population growth rate over the past two decades has been influenced by declines in fertility rates as well as international migration. The population was 50.7 per cent female and 49.3 per cent male in 2008; it was 53.5 per cent urban vs. 46.5 per cent rural in 2007[4]. Approximately 43.3 per cent of the population resided in the Kingston Metropolitan Region. Poverty has been declining: from just under 20 per cent in 2000 to just below 10 per cent in 2007.

Economic growth over 2000-08 has been less than favourable. Over the past decade, the rate of growth of the gross domestic product (GDP) ranged between 3.5 percent and -0.6 percent. This was caused in part by external factors such as the September 2001 terrorist attack on the United States of America (USA) and the SARS pneumonia outbreak in 2003 which adversely affected tourism; unprecedented rises in oil prices in 2007 and 2008 and the global recession that started in 2008. In addition, there were the local effects of hurricanes – Michelle (2001), Ivan (2004), Dennis, Emily, and Wilma (2005), Dean (2007), and Gustav (2008)[5]. The average annual exchange rate of the Jamaican dollar against the US dollar rose from 43 in 2000 to 80 in 2008. Oil prices increased 52 percent in

2005, 20 percent in 2006, and 70 percent in 2008. This was particularly significant since Jamaica depends on imported petroleum to meet 95 per cent of its energy needs.

Towards the end of 2008, there was sharp contraction in global financial markets which, among other things, led to depreciation of the value of the Jamaican dollar and negatively impacted bauxite, tourism and agriculture. Towards the end of 2009, the impacts of the global recession continued to take effect in Jamaica, which saw the closure of three of its four alumina plants (Alpart, Windalco's Ewarton and Kirkvine Works).

The gross value added of industrial sectors to GDP in Jamaica for 1999-08 and the percent contribution are presented in Tables 3.2 and 3.3.

Table 3.2: Gross Value Added By Industry At Constant (2003) Prices (1999-08), in $' Million

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Agriculture, Forestry & Fishing	30,547.5	26,675.9	28,458.4	26,521.4	28,389.8	25,196.5	23,490.6	27,286.1	25,696.1	24,362.1
Mining & Quarrying	17,483.4	17,429.3	17,942.8	18,312.5	19,233.6	19,659.3	20,212.9	20,395.6	19,863.8	19,370.4
Manufacture	47,942.2	47,135.4	46,771.7	45,838.7	45,597.4	46,245.2	44,214.6	43,224.6	43,541.2	42,924.7
Electricity & Water Supply	14,039.8	14,314.7	14,408.7	15,072.6	15,782.4	15,761.8	16,416.4	16,949.3	17,043.8	17,197.7
Construction	35,552.0	35,632.2	35,570.3	35,222.7	37,001.4	40,126.5	43,124.9	42,297.2	44,230.2	41,286.1
Wholesale & Retail Trade, Repairs & Installation of Machinery	85991.9	88,100.9	87,845.8	88,205.7	89,668.2	91,017.2	92,329.5	94,402.5	96,039.7	95,877.8
Hotels & Restaurants	85,991.9	21,911.8	21,632.3	21,685.1	22,686.5	23,664.4	24,733.5	27,230.4	27,320.6	27,929.9
Transport, Storage & Communication	20,814.2	49,015.2	51,375.2	54,553.6	56,747.8	57,546.0	58,068.2	60,651.5	62,664.7	61,250.6
Finance & Insurance Services	45,944.2	44,001.1	46,617.0	49,533.3	52,898.8	54,379.4	54,132.3	55,383.8	57,268.5	57,738.8
Real Estate, Renting & Business Activities	42,250.2	43,754.0	44,133.4	44,383.4	45,359.3	46,233.9	46,871.2	47,679.2	49,190.1	49,800.9
Producers of Government Services	43,825.4	56,679.9	57,454.4	57,941.8	58,055.2	58,144.2	58,294.0	58,579.1	59,365.5	59,322.9
Other Services	56,898.2	28,504.9	28,555.5	29,287.0	30,504.6	31,228.0	32,078.2	33,380.1	34,075.6	34,238.8
Less Financial Intermediation Services Indirectly Measured	*28,120.1*	*23,020.2*	*24,576.4*	*25,941.9*	*25,179.1*	*25,577.5*	*25,482.7*	*25,713.4*	*27,050.9*	*26,879.0*
Total Gross Value Added At Basic Prices	**446,214.2**	**450,135.1**	**456,189.2**	**460,616.0**	**476,745.8**	**483,624.7**	**488,483.5**	**501,746.1**	**509,248.9**	**504,421.7**

Sources: From Bank of Jamaica Statistical Digest May 2009; Table 46.2 Gross Domestic Product Value Added By Industry At Constant (2003) Prices, 1998-2007.
http://statinja.gov.jm/VALUEADDEDBYINDUSTRYATCONSTANT%282003%29PRICES.aspx

Table 3.3: Percent Contribution to Total Goods and Services Production in Basic Values at Constant (2003) Prices (1999-08)

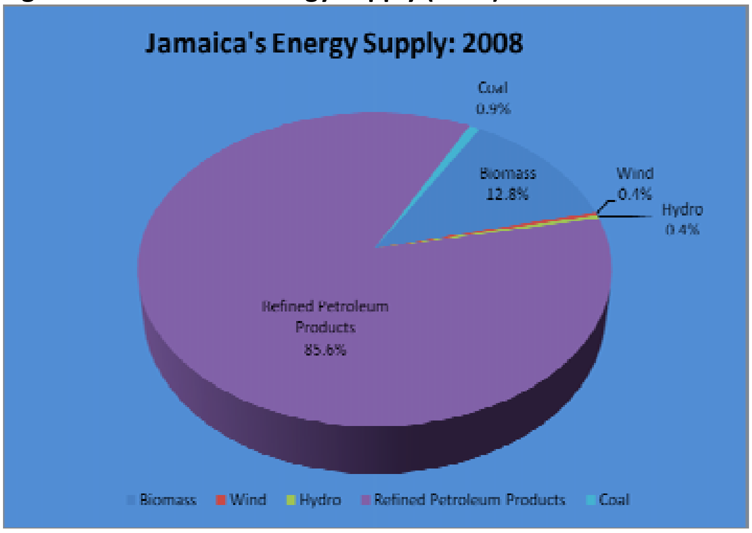
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Agriculture, Forestry and Fishing	6.8	5.9	6.2	5.8	6.0	5.2	4.8	5.4	5.0	4.8
Mining and Quarrying	3.9	3.9	3.9	4.0	4.0	4.1	4.1	4.1	3.9	3.8
Manufacture	10.7	10.5	10.3	10.0	9.6	9.6	9.1	8.6	8.5	8.5
Electricity and Water Supply	3.1	3.2	3.2	3.3	3.3	3.3	3.4	3.4	3.4	3.4
Construction*	8.0	7.9	7.8	7.6	7.8	8.3	8.8	8.4	8.7	8.2
Wholesale & Retail Trade, Repairs & Installation of Machinery	19.3	19.6	19.3	19.1	18.8	18.8	18.9	18.8	18.9	19.0
Hotels & Restaurants	19.3	4.9	4.7	4.7	4.8	4.9	5.1	5.4	5.4	5.5
Transport, Storage and Communication	4.7	10.9	11.3	11.8	11.9	11.9	11.9	12.1	12.3	12.1
Finance & Insurance Services	10.3	9.8	10.2	10.8	11.1	11.2	11.1	11.0	11.2	11.4
Real Estate, Renting & Business Activities	9.5	9.7	9.7	9.6	9.5	9.6	9.6	9.5	9.7	9.9
Producers of Government Services	9.8	12.6	12.6	12.6	12.2	12.0	11.9	11.7	11.7	11.8
Other Services	12.8	6.3	6.3	6.4	6.4	6.5	6.6	6.7	6.7	6.8
Less Financial Intermediation Services Indirectly Measured (FISIM)	6.3	5.1	5.4	5.6	5.3	5.3	5.2	5.1	5.3	5.3
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
GDP at 2003 Prices (J$ Billions)	**446.2**	**450.1**	**456.2**	**460.6**	**476.7**	**483.6**	**488.5**	**501.7**	**509.2**	**504.4**

Sources: From Bank of Jamaica Statistical Digest May 2009; Table 46.1 Percentage Contribution Of Gross Domestic Product Value Added By Industry At Constant (2003) Prices, 1998-2007; Data for 2008 derived from STATIN: Gross Value Added By Industry At Constant(2003) Prices, 2004 - 2008 $' Million. http://statinja.gov.jm/VALUEADDEDBYINDUSTRYATCONSTANT%282003%29PRICES.aspx

3.1.1 Jamaica's Energy Sector Profile

Jamaica has no known primary petroleum or coal reserves and imports all of its petroleum and coal requirements. Domestic energy needs are met by burning petroleum products and coal and renewable fuel biomass (i.e., bagasse, fuel wood, and charcoal) and from using other renewable resources (e.g., solar, wind and hydro). Figure 3.1 illustrates that in 2008 approximately 86 per cent of the energy mix is imported petroleum, with the remainder coming from renewables and coal. The data for Figure 3.2 excluded fuel supplied for international bunkers. Electricity is generated primarily by oil-fired steam, engine driven, and gas turbine units. Smaller amounts of electricity are generated by hydroelectric and wind power. Use of solar energy is negligible and is limited to a few solar water heaters and solar crop dryers.

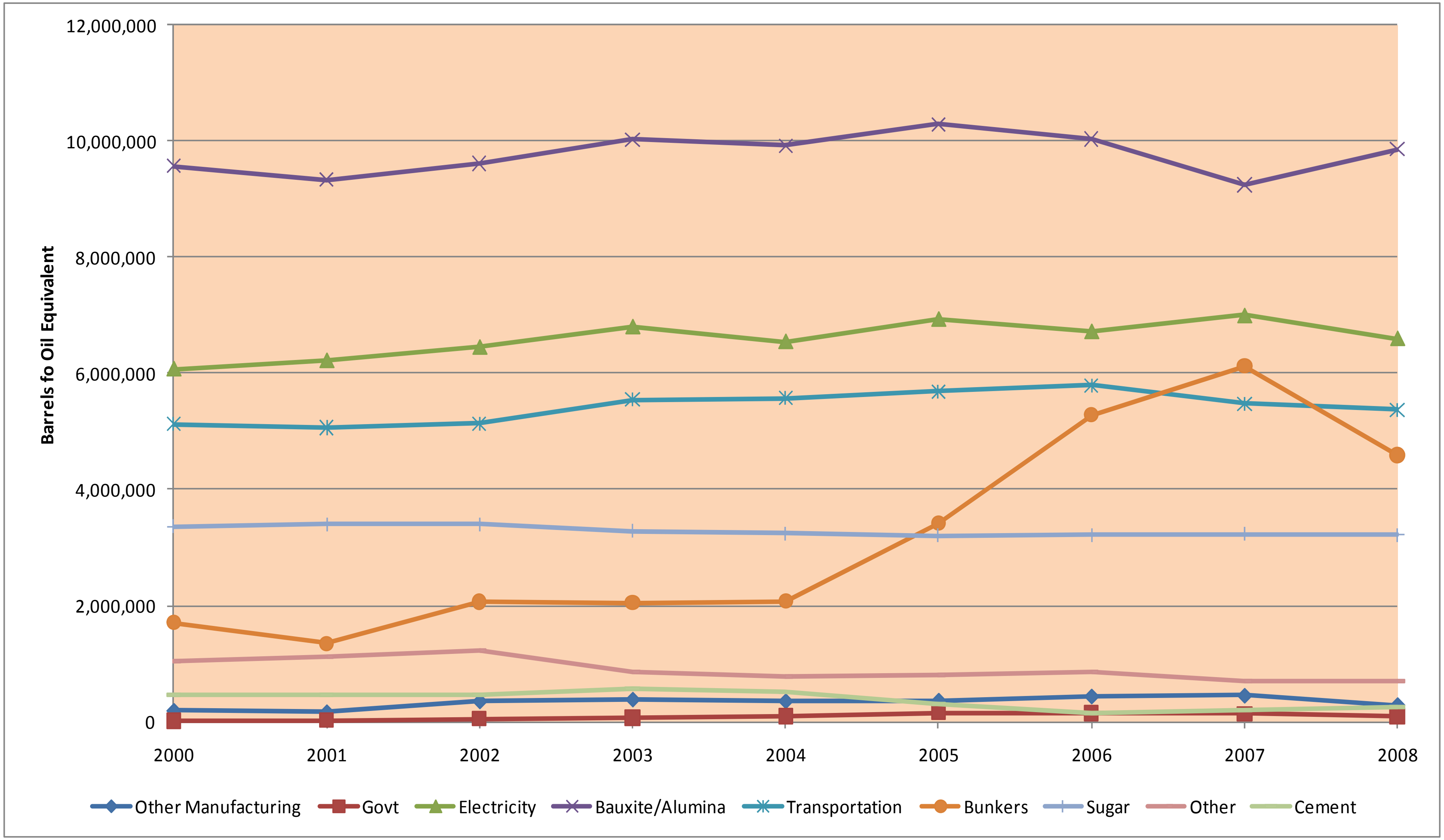
Figure 3.1: Jamaica's Energy Supply (2008)



The Petrojam refinery, which has a nameplate capacity of 35,000 barrels per stream day (bsd), provides some of the refined petroleum products and the remainder is imported. Petrojam is a state-owned enterprise and the electric utility – the Jamaica Public Service Company Limited (JPS) – is 80.1 percent privately owned and the remainder government owned. JPS is the sole distributor of electricity to the public and it generates the majority of the electricity sold to the public. The remainder is purchased from independent privately owned power producers (IPPs). A small amount of electricity is generated by industrial, commercial or residential operators for their own use. The petroleum product market is open and Petrojam, along with multinational petroleum marketing companies, imports refined petroleum products. Heavy fuel oil needed by the bauxite alumina industry is imported directly by the industry.

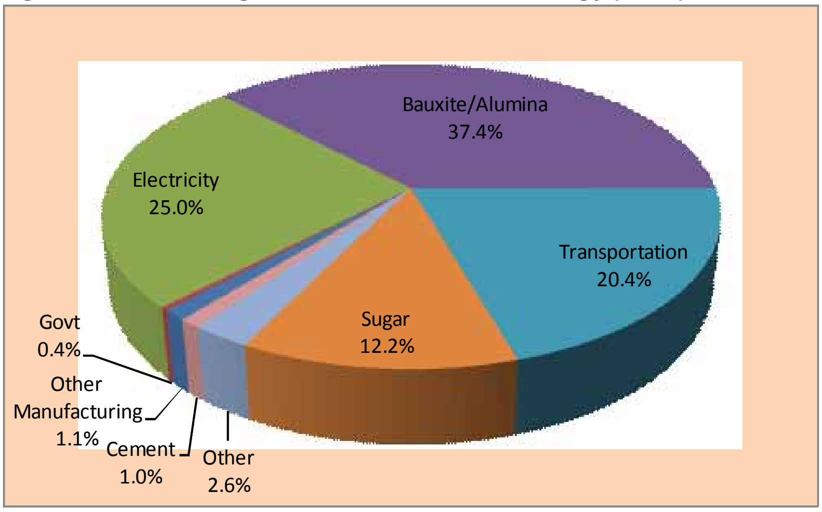
Energy consumption by end-use activity between 2000 and 2008 is shown in Figure 3.2, which shows the sectors that use energy and also includes the fuels supplied to international bunkers. The latter are not counted as part of Jamaica's energy consumption since consumption of these fuels occurs outside Jamaica's borders.

Figure 3.2: Jamaica's Energy End Use and International Bunkers (2000-08)



The bauxite and alumina industry has the largest percentage end use, which was 37.4 percent in 2008 (Figure 3.3), followed by electricity generation (25%), transportation (20.4%) and then the sugar industry (12.2%). The majority of the fuel used in the sugar industry is bagasse, with much smaller amounts of heavy fuel oil and wood and while the other sectors use petroleum products nearly exclusively. The exceptions are coal in the cement industry and small amounts of wood used at one lime kiln. In making the sectoral assignments from the data provided by MEM, it was assumed that all gasoline consumption was for transportation. Small quantities of gasoline are used for domestic marine vessels but it was not feasible to allocate fuel consumption for domestic marine purposes. Initially all of the turbo and aviation gasoline was attributed to international bunkers but were adjusted downwards by the estimates of fuel used for landings and take offs and internal flights. Details of the methodology for estimating fuel use and emissions from domestic flights are provided in the national GHG emission inventory[6] (Chapter 2). Estimates of charcoal use (included in the "Other" sector are subject to considerable uncertainty since the production and distribution of charcoal is in the informal economy.

Figure 3.3: Percentage End Use of Jamaica's Energy (2008)



Sources: Ministry of Energy and Mining; Cement Company; Jamaica Bauxite Institute, Sugar Industry Research Institute. Preference was given to primary data sources when these data were available.

3.1.2 National Institutions and Agencies Related to Implementation of Mitigation Actions

The key institutions involved in climate change mitigation are the same as those that are involved in the implementation of Jamaica's National Energy Policy (2009-30). Goal 5 of the Energy Policy speaks to Jamaica having well-defined and established governance, institutional, legal and regulatory framework for the energy sector that facilitates stakeholder involvement and engagement. The policy also plans to ensure that the (energy sector) institutional framework includes mechanisms for improved coordination and organization between and within energy agencies and capacity building to meet the human resource needs.

Since climate change and mitigation issues affect nearly all public and private sector institutions and every facet of life, it will be necessary to focus on those institutions and their policies and legislation under whose portfolios there are highest GHG emissions and opportunities for mitigation. The highest GHG emissions occur in the transport, transformation (electricity generation and petroleum refining), and the mineral processing (alumina and cement manufacture) sectors. Implementation of mitigation activities invariably will need facilitating and supporting roles from other institutions to provide suitable financial incentives, assessment and analysis of outcomes, public relations and public education. These institutions and the existing policies and legislation are described below in order to identify issues that could present barriers and/or facilitate implementation of GHG mitigation activities.

A detailed analysis of the existing energy sector institutions was beyond the scope of this assessment but it is noted that the Energy Policy includes strategies to review and modify the existing institutional framework and industry structure as well as the legal and regulatory frameworks for the energy sector.

Key Institutions Directly Involved In GHG Mitigation

Ministry of Energy and Mining (MEM): The Ministry of Energy and Mining (MEM) has the dual responsibilities of articulating Jamaica's National Energy Policy and coordinating the monitoring of its implementation. The Ministry, along with its agencies, is responsible for establishing the legislative and policy framework to facilitate the achievement of Jamaica's national energy goals, which have implications for the mitigation activities and projections outlined in this assessment. It also provides the necessary guidelines for its agencies for general medium and long-term energy strategy planning. MEM, in collaboration with its agencies and several other Government entities as well as other partners and stakeholders in the public and private sectors, is also leading the development of a carbon trading policy[7].

MEM, in setting indicators and targets for the energy sector, will also be mindful of the mitigation activities as well as the projections and take into account key issues such as need for the use of cleaner technologies in industry as well as enabling a more efficient energy sector in general as well as leading various initiatives for the diversification of energy.

The Petroleum Corporation of Jamaica (PCJ): The Petroleum Act of 1979 established PCJ as a Statutory Corporation under MEM, with the exclusive right to explore for oil, to develop Jamaica's petroleum resources, and to enter all stages of the petroleum industry. The PCJ Group has subsidiaries Petrojam Limited, which operates the oil refinery, Petrojam Ethanol Limited, Petcom Limited, the marketing and retailing company, Jamaica Aircraft Refuelling Services and Wigton Wind farm Limited. The Petrojam refinery is the only refinery in Jamaica. Together with privately owned petroleum marketing companies, it supplies refined petroleum products for the Jamaica market.

PCJ assists with implementing Jamaica's National Energy Policy while promoting sustainable development, not only in energy, but also in other areas of national importance with the aim of fostering energy security. PCJ, in its role of undertaking the development and promotion of Jamaica's indigenous energy resources and all forms of renewable energy, will have a fundamental role in Jamaica's mitigation efforts especially as it relates to the introduction of as much as 20 percent renewables in the energy mix by 2030. Towards this end, as of November 2009, all of Jamaica's gasoline will be based on E10.

In 2006, PCJ established a Centre for Renewable Energy (CERE) to support the research, promotion and development of renewable fuels and electricity from renewable sources for the Jamaican market. CERE plans to partner with tertiary institutions and collaborate with government and private sector agencies that strike the proper balance between environmental protection, economic growth and the demonstration of renewable energy sources.

The Jamaica Bauxite Institute (JBI): The bauxite and alumina sector is the largest end user of energy in Jamaica, accounting for just over 37 percent of Jamaica's energy demand in 2008. In 2009, the sector had one operating alumina refinery (Jamalco) and one company that mined and exported bauxite. Three alumina plants (Alumina Partners (Alpart) and two Windalco plants (Kirkvine and Ewarton)) were closed in 2009. The Jamaican Government owns 45 percent of the Jamalco, 7 percent of the Windalco and 51 percent of the St Ann Jamaica Bauxite Partners (SAJBP) operations.

JBI was established in 1976 as an arm of the Jamaica National Investment Company (now the Development Bank of Jamaica, to deal mainly with the sovereign aspects of the Government's participation in the bauxite and alumina industry. JBI's functions include:

- monitoring and studying the aluminum industry;
- providing technical advice;
- undertaking research and development activities;
- assessing and ensuring rationalization in the use of Jamaica's bauxite reserves and (bauxite) land; and
- monitoring and making recommendations on pollution control and other environmental concerns in the industry.

JBI also manages the Bauxite Community Development Programme, which involves implementation of development projects within the vicinity of bauxite and alumina operations, to foster harmony between the community and the companies.

JBI works in collaboration with other agencies, and is proactive in attaining compatibility between the industry's operations (processes, activities and products) and the environment by:

- ensuring that the operations are conducted with minimal or no adverse impact on the environment;
- ensuring compliance with all local standards and regulations through maintaining a regular and effective monitoring programme;
- conducting regular reviews on the environmental performance of the industry and instituting the necessary corrective actions;
- promoting research and development aimed at identifying new technologies for a cleaner, more efficient production process and waste minimization; and
- fostering and maintaining a harmonious relationship with communities in the vicinity of bauxite/alumina operations.

Electricity generating companies: Jamaica's electricity is generated by the Jamaica Public Service Company Limited (JPS) and privately owned, independent power producers (IPPs) – Jamaica Energy partners (JEP) and Jamaica Private Power Company (JPPC). JPS was privately owned until 1970 when the Government of Jamaica acquired a controlling interest. In 2001, the Government retained 20 percent of the company and sold the remainder of its holdings to Mirant, which in 2007 sold its majority shares to Marubeni Caribbean Power Holdings (MCPH) Inc, a subsidiary of Marubeni Corporation of Japan. In early 2009, Marubeni transferred 50 percent of its shares in MCPH to Abu Dhabi National Energy Company (TAQA) of the United Arab Emirates.

JPS uses steam (heavy fuel oil-fired), gas turbines, combined cycle, slow speed diesel engines and hydropower while the IPPs use slow/medium speed diesel engines and wind turbines. JPS also purchases power from one supplier (Jamalco) that uses cogeneration. In 2008, the generating capacities of JPS and the IPPs were 621 MW and 89 MW respectively. The bauxite and alumina companies and sugar factories also generate electricity for their own use.

JPS is the sole distributor of electricity to a customer base of over 600,000. While JPS has the exclusive right to under its Licence "to transmit, distribute and supply electricity throughout Jamaica" until 2021, effective April 2004 the Licence provides for the addition of generating capacity through a competitive process.

The Office of Utility Regulation (OUR): The OUR was established by an Act of Parliament in 1995 to regulate the operations of utility companies in Jamaica. The OUR is responsible for regulating the provision of electricity, telecommunications, water & sewerage, public transportation by road, rail and ferry services. The main objectives of the OUR are to:

- ensure consumers of utility services enjoy an acceptable quality of service at reasonable cost;
- establish and maintain transparent, consistent and objective rules for the regulation of utility service providers;
- promote the long-term efficient provision of utility services for national development consistent with Government policy;
- provide an avenue of appeal for consumers who have grievances with the utility service providers;
- work with other related agencies in the promotion of a sustainable environment; and
- act independently and impartially.

OUR makes utility rate applications and supporting information publicly available. This was a key source of information on the electricity generating sector for this mitigation assessment. OUR also sets the regulatory policy to guide the process for the addition of new generating capacity to the public electricity supply system. Currently, contractual arrangements (i.e., the Power Purchase Agreement (PPA) between the parties) for the supply of power is negotiated between JPS and the investor supplying power but the PPA must be approved by the OUR before being made effective.

The Ministry of Transport and Works (MTW): MTW's primary responsibility is for Jamaica's land, marine, and air transport, as well as the main road network, including bridges, drains, gullies, embankments and other such infrastructure. MTW has regulatory responsibility for the safety of all publicly or privately operated modes of transportation. This includes airports, aerodromes, airline operators, sea ports, shipping traffic, and public land transportation, as well as road infrastructure and road safety. The infrastructure includes a 15,394 km road network, 330km of rail track, a large fleet of public passenger buses, two international airports, four domestic aerodromes, ten specialised sea ports and three public deep-water ports.

There are 21 reporting entities that assist MTW in fulfilling its mandate. Among them are the Transport Authority (TA), the Island traffic Authority (ITA), the Civil Aviation Authority (CAA), Airports Authority of Jamaica (AAJ), and the Port Authority of Jamaica (PAJ). The Jamaica Urban

Transit Company (JUTC) and the Montego Bay Metro Bus Company (MBM) operate public passenger transport services in the Kingston Metropolitan Transport Region and Montego Bay respectively.

The Transport Authority regulates licensing of all public and commercial vehicles and the regulating and monitoring of public transportation. The Island Traffic Authority administers the provisions of the Road Traffic Act, and is responsible for the testing of vehicles to ensure fitness, road-worthiness and general compliance with standards of safety. Vehicle registration information for the entire vehicle fleet is maintained by the Inland Revenue. Departments in the Ministry of Finance and the Island Transport Authority and Transport Authority also have additional data relating to their areas of jurisdiction.

Supporting Energy Sector Institutions and Agencies

The Office of the Prime Minister (OPM): The OPM is responsible for the environment; the Environment Management Division is housed within OPM. The last Designated National Authority for the Clean Development Mechanism (CDM) was within the EMD, but due to the wording of the DNA assignment and a change in ministerial assignment for EMD the DNA needed to be reassigned. Among the agencies reporting to OPM are the National Environment and Planning Agency (NEPA), National Solid Waste Management Authority (NSWMA), the Statistical Institute of Jamaica (STATIN), the Planning Institute of Jamaica (PIOJ), and the Meteorological Service.

NEPA is the agency entrusted with managing Jamaica's natural and the man-made environment and is the lead government agency responsible for environmental management and spatial planning in Jamaica.

NSWMA is responsible for establishing the standards and criteria that must be attained by operators in the solid waste sector and for the collection and disposal of municipal solid waste. NSWMA currently operates eight waste disposal sites in seven parishes that serve the entire country.

STATIN's main functions are to:

- collect, compile, analyse, abstract and publish statistical information relating to the commercial, industrial, social, economic and general activities and condition of the people;
- collaborate with public agencies in the collection, compilation and publication of statistical information including statistical information derived from the activities of such agencies;
- take any census in Jamaica; and
- generally promote and develop integrated social and economic statistics pertaining to Jamaica and to co-ordinate programmes for the integration of such statistics, in accordance with the provisions of the Statistics Amendment Act (1984).

PIOJ is the foremost planning agency of the government and its functions as stipulated in the PIOJ Act include:

- initiating and coordinating the development of policies, plan and programmes for the economic, financial, social, cultural and physical development of Jamaica;
- undertaking research on national development issues;
- providing technical and research support to the Cabinet;
- undertaking consultant activities for local and foreign Government entities;
- managing external cooperation agreements and programmes;

- collaborating with external funding agencies in the identification and implementation of development projects; and
- maintaining a national socio-economic library.

The National Meteorological Service is the focal point for climate change in Jamaica.

The Ministry of Finance and the Public Service: The Ministry of Finance and the Public Service has responsibility for the macro-economy which includes implementing tax related incentives/disincentives for the development of all sectors including the energy sector. The Inland Revenue Department maintains the database with registration information for the licensed motor vehicle fleet.

The Forestry Department: The Forestry Department is an Executive Agency of the Ministry of Agriculture and is the lead agency responsible for the management and conservation of Jamaica's forests. Its functions are mandated by the Forest Act, 1996, and are aimed at managing forests on a sustainable basis to maintain and increase the environmental services and economic benefits that forests provide. A National Forest Conservation and Management Plan and the Strategic Forest Management Plan 2009-13[8], among other things, describe the Department's policy and legal framework, forest management constraints, forest values, the current state of Jamaica's forests and establish goals and a wide range of implementation forest management strategies and activities.

The Jamaica Bureau of Standards (BSJ): BSJ is a statutory body established by the Standards Act of 1968. Its main functions are formulating, promoting and implementing standards for goods, services and processes. The Bureau develops and enforces technical regulations for those commodities and practices which affect health and safety. It is the agency that sets fuels specifications.

The Government Electrical Inspectorate: The Government Electrical Inspectorate (GEI) is the government agency within the Ministry of Industry, Investment and Commerce with responsibility for certifying all electrical installations to ensure that they meet the required standards. GEI certification is needed for all new constructions, for premises that have been rewired or which have undergone any kind of renovation.

3.1.3 Key Policies and Legislation Related to Implementation of Mitigation Actions

Vision 2030 Jamaica: National Development Plan provides the overarching context within which Jamaica's mitigation activities will take place. It includes two national strategies – *Develop measures to adapt to climate change* and *Contribute to the effort to reduce the global rate of climate change* – that specifically speak to the strategies and actions that Jamaica will employ to reduce its GHG emissions to 2030. Vision 2030 articulates, *"Mitigation, through reducing greenhouse gas emissions, will be addressed through greater energy conservation. Energy conservation in Jamaica will put us in a "win-win" situation as it provides other substantial positive economic, social and environmental benefits. As described earlier in National Outcome 10 of the Plan, energy conservation efforts, use of cleaner technologies and development of alternate energy will result in lower spending on imported oil, less pollution and reduction in pollution-related illnesses. We will engage in reforestation to increase the amount of greenhouse gases removed from the atmosphere, provide improved watersheds and waterways and reduce landslides and soil erosion. These measures (energy* *conservation and reforestation), if pursued on a global scale, will mitigate and reduce the global rate of climate change".*

National Energy Policy 2009-30

In December 2009, the government tabled a *National Energy Policy 2009-30* in Parliament that will lead toward developing:

> *A modern, efficient, diversified and environmentally sustainable energy sector providing affordable and accessible energy supplies with long-term energy security and supported by informed public behaviour on energy issues and an appropriate policy, regulatory and institutional framework.*

This vision will be realized by translating the policy into strategies and specific areas of action, such as diversification of the country's existing fuel sources, development of renewable sources of energy, biofuels, and waste-to-energy programmes, to name a few. These strategies and actions are being administered through the corporate and operational plans in a range of organizations, starting with the Ministry of Energy and Mining (MEM) and its agencies, and also including other Ministries, agencies and departments such as those ministries with responsibilities for transport, agriculture, and environment.

The policy places priority attention on seven key areas:

1. Security of energy supply through diversification of fuels as well as development of renewable energy sources;
2. Modernizing the country's energy infrastructure;
3. Development of renewable energy sources such as solar and hydro;
4. Energy security and efficiency;
5. Development of a comprehensive governance/regulatory framework;
6. Enabling government ministries, departments and agencies to be model/leader for the rest of society in terms of energy management; and
7. Eco-efficiency in industries.

Each of these seven priority areas, when implemented, will reduce Jamaica's GHG emissions and they have been included in the scenarios in this mitigation assessment. Other policies to be developed that will also help in the reduction of GHG emissions include the Renewable Energy Policy, the Biofuels Policy, and the Energy Conservation and Efficiency Protocol (ECE) for the management and use of energy in the public sector. The ECE speaks to the operation of public sector facilities and entities.

The framework for the implementation of the National Energy Policy is presented in Figure 3.4.

Figure 3.4: Implementation Framework for Jamaica's National Energy Policy

Jamaica's Energy Management Framework

Jamaica's energy management framework and particularly this policy will support Vision 2030 Jamaica – National Development Plan, particularly National Outcome #10 – Energy Security and Efficiency and is therefore consistent with, and part of the overarching vision for achieving developed country status by 2030[1]. The National Energy Policy and its relationship to Vision 2030 Jamaica as well as Government's policy-making framework are presented in the matrix below:

"Jamaica, the place of choice, to live, work, raise families and do business"
(Jamaica's National Vision)

"A modern, efficient, diversified and environmentally sustainable energy sector providing affordable and accessible energy supplies with long-term energy security and supported by informed public behaviour on energy issues and an appropriate policy, regulatory and institutional framework"
(Vision of Jamaica's Energy Sector)

Goal 1:	Goal 2:	Goal 3:	Goal 4:	Goal 5:	Goal 6:	Goal 7:
Jamaicans use energy wisely and aggressively pursue opportunities for conservation and efficiency	Jamaica has a modernized and expanded energy infrastructure that enhances energy generation capacity and ensures that energy supplies are safely, reliably, and affordably transported to homes, communities and the productive sectors on a sustainable basis	Jamaica realizes its energy resource potential through the development of renewable energy sources and enhances its international competitiveness, energy security whilst reducing its carbon footprint	Jamaica's energy supply is secure and sufficient to support long-term economic and social development and environmental sustainability	Jamaica has a well-defined and established governance, institutional, legal and regulatory framework for the energy sector, that facilitates stakeholder involvement and engagement	Government ministries and agencies are a model/leader in energy conservation and environmental stewardship in Jamaica	Jamaica's industry structures embrace eco-efficiency for advancing international competitiveness and moves towards building a green economy

Energy Strategies and Key Actions to 2030

Implementation Framework (Energy Specific Plans, Vision 2030 Jamaica Action Plans/3yr Corporate Plans of Ministries, Agencies and Departments)

Monitoring and Evaluation Framework (Energy Targets and Indicators)

Policy Review (3-yearly, and consistent with GOJ Policy Review Framework)

[1] As articulated in Vision 2030 Jamaica – National Development Plan

Securing Jamaica's Energy Future | Page viii

The National Transport Policy[9] drafted in 2007 is guided by the vision to create a "sustainable, competitive, safe, accessible, and environmentally friendly transport network providing world class air, land, rail, and marine facilities contributing to a vibrant import, export and trans-shipment trade for Jamaica and the world." The transport policy is designed to encourage energy conservation measures (e.g., efficient traffic management; car pooling; park and ride; use of clean fuels to minimize pollution; flexi-work hours and tele-commuting; an efficient public/urban mass transit transport system; and use of non-motorized transport) and promotion of vehicle and road maintenance programmes. Supporting legislation for use of biofuels will be put in place.

The transport policy also will encourage more efficient modes of transport such as barges especially for bulky materials like aggregates. The possibility of enhanced coastal and rail transport will be kept under constant review. The policy foresees that once natural gas is introduced into Jamaica's energy supply mix, the transport fleets, where applicable, will be converted to CNG. In the longer term, a CNG supply network will be developed to enable private motorists to convert to natural gas based motor vehicles.

The Forestry Department's Strategic Forest Management Plan: 2009-13 will enable it to fulfil its mission to manage, protect and conserve the country's forest resources[10]. The Forest Management Plan specifically refers to the mandate to maintain and measure the role of forests as carbon sinks as part of Jamaica's commitments under the UN Framework Convention on Climate Change (UNFCCC).

The draft Carbon Emissions Trading Policy (2009) sets out a comprehensive framework for Jamaica's participation in the carbon trading market. It presents the Government's positions, defines investment priorities, establishes the institutional and legal framework, and facilitates structures necessary for the effective management of the regime involving the participation of all sectors in a manner that is mutually beneficial to all. The overarching objective is to position Jamaica to capitalize further on opportunities for partnerships with other developed countries, private organizations, as well as relevant regional or international institutions. This will generate social, economic and environmental benefits for the country through investment in initiatives that will also foster sustainable development goals.

OUR issued the Regulatory Policy for the Addition of New Generating Capacity to the Public Electricity Supply System that guides the process for the addition of new generating capacity to the Jamaican electricity grid. The policy is a complement to the *All Island Electric Licence, 2001* which gives JPS the exclusive right to transmit and distribute electricity and, as of 2004, the right to compete with other electricity producers for the opportunity to develop new generation capacity. This OUR policy has accompanying schedules that detail the procedures by which capacity can be added to the system and it is intended to facilitate the long term expansion of generation at the least economic cost while giving due regard to the relevant policies and applicable legislation. According to the policy, the addition of new capacity to the grid can be achieved by:

- the installation of conventional technologies,
- the utilization of renewable sources, and;
- the setting up of co-generation installations

The policy was drafted as part of the government's goal of enabling national government entities to become more efficient in their operations, generating significant cost savings while eliminating or minimizing adverse impacts on the environment. The policy speaks to among other things, energy conservation, water conservation, and fleet management – aspects of government operations that have an impact on the overall use of energy.

The agencies and institutions described above all have enabling legislation that empowers them to undertake their functions. Implementing the various mitigation measures and assessing the current and future mitigation options requires institutions and agencies with the institutional and legislative frameworks that will facilitate the construction and operation of mitigation projects and activities as well as the collection and analysis of relevant information that will monitor their implementation and assess new development possibilities. The legislation most important for the mitigation assessment is described below.

The Electricity Survey Act (1956) allows for the collection, compilation and analysis of information relating to the generation, distribution and use of electricity, and the quantities and types of electrical apparatus in use.

The Petroleum Quality Control Act includes regulations that require reporting of fuel sales information by petroleum marketing companies. Licences issued by OUR also have reporting requirements.

The Natural Resources Conservation Authority Act (1991) provides for the management, conservation, and protection of Jamaica's natural resources. The Act establishes the Natural Resources Conservation Authority (NRCA), whose functions include the taking of such steps that are necessary to ensure the effective management of the physical environment of Jamaica. Section 9 of the Act gives Ministerial discretion to declare parts of or the entire island a 'prescribed area', in which specified activities require a permit, and for which activities an environmental impact assessment may be required. The Natural Resources Conservation Authority (Permits and Licences) Regulations (1996) sets categories of enterprises that will require a permit for their development or construction and the requirements for licences for those enterprises. The Natural Resources Conservation Authority (Air Quality) Regulations (2006) sets out the criteria that determine which facilities require a licence to discharge certain pollutants and prescribe discharge fees. The regulations also include a requirement that licensees provide annual emissions reports for emissions of the so called regulated pollutants and greenhouse gases.

3.2 Methodological Approach

The Long-Range Energy Alternatives Planning System (LEAP) model[11] was used for the mitigation assessment to examine the demand, transformation, resources, and non-energy sector emissions and effects. LEAP is a scenario-based, energy-environment modelling tool based on a comprehensive accounting of how energy is consumed, converted and produced in a given region or economy under a range of alternative assumptions.

The base year used in the analysis was 2000 – the same year used for compilation of the national GHG emission inventory. Historical data from 2000-08 were used and projections were made for 2009 to 2035 for three groups of scenarios: the **Reference Scenario, Scenario 2** and **Scenario 3**. Scenarios are self-consistent story-lines of how a future energy system might evolve over time in a particular socio-economic setting and under a particular set of policy options defined for example by specific projects and measures. Scenarios in LEAP can be compared to assess their energy requirements, environmental impacts and social costs and benefits.

The input data for the LEAP model are grouped into five categories:

1. *Key assumptions*, i.e., macroeconomic, demographic and other time-series variables used in other categories;
2. *Demand*: Overall energy consumption of households, industry, government, road transport, and various JPS electricity customer rate classes;
3. *Transformation*, i.e., petroleum refining, electricity distribution and generation, charcoal production;
4. *Resources*: indigenous energy resources; and
5. *Non-energy sector effects*, i.e., GHG emissions from cement and lime manufacturing, GHG emissions from agriculture, forestry and industry.

Detailed data was obtained for the sub-categories listed in Table 3.4. Additional information about these sub-categories follows.

Table 3.4: LEAP Model Input Data

Key Assumptions	• Population • Household Size • GDP in J2003$ • Population growth rate • Household size • GDP Growth Rate • Transportation Emission factors (for 11 pollutants in 8 vehicle classes)
Demand	• Household (Refrigeration, Lighting, Cooking, Fans, Stereo, Air conditioners, Computer equipment, Washing machines, Clothes ironing, Television, All other • Industry (Cement & Clinker, cement mills, Bauxite mining#, Bayer Process, Alumina Kilns, Lime kilns, Sugar) • Government (Hospitals, NWC, Other Government) • Municipal (Rate 60) • Rate 20, Rate 40A##, Rate 50 • Road Transport (8 vehicle classes) • Commercial charcoal
Transformation	• Transmission & Distribution • Oil Refining • Electricity Generation • Charcoal making • Coal gasification
Natural Resources	• Primary (Wind, Hydro, Wood, Bagasse, Municipal Waste, Peat) • Secondary (Output fuels)
Non-Energy Sector Effects	• Landfill emissions • Agriculture (Animals, Soils, Rice Production, Forestry) • Industry (Lime kilns, Cement, Pet Coke limestone)

Bauxite mining includes rail transportation
Rate 40A defined to avoid double counting – see text

3.2.1 LEAP Model Information Sources

Key Assumptions

This module contains macroeconomic (GDP and GDP growth rate), demographic (population, population growth rate, household size) and other time-series variables (for example, emission factors for the on-road fleet) that are used in the other modules.

Historical and projected GDP data were obtained from the PIOJ and Bank of Jamaica publications (see footnotes in Tables 3.2 and 3.3). The population and number of households' data were obtained or derived from information published by STATIN and in the annual Economic and Social Survey Jamaica (ESSJ) reports or Bank of Jamaica Reports. Emission factors for pollutants emitted by various vehicle classes were obtained from outputs of a transportation model (MOBILE6).

Demand

The demand module requires activity and energy intensity data such that the product of the two gives the energy consumption. The demand module was broken down into various "branches" namely, household, industry, government, road transport, and various electricity customer rate classes used by JPS. These branches were selected because fuel and electricity end-use and other activity data are available for them and/or subcategories within them. The methodologies applied for the various demand branches are described below. Additional details for future activity and energy intensity information are provided in the following section on scenarios.

*Household*s

The 2001 census[12] and Jamaica Survey of Living Conditions (JSLC) 2007[13] provided detailed household (residential) data for the numbers of households that have or use various types of household amenities or appliances. Appliances with small penetration (i.e., low percentages of households have them) and/or low annual energy use or little prospect for increased penetration were grouped under "All other". Additional household data were also obtained from a recent survey of residential energy end use[14].

Since the available residential (JPS Rate 10) electricity consumption data are for customers (not households), it was assumed that the percentages of households with the various amenities and appliances were the same as the percentages of customers with them. The best fit relationship between the ratio of customers to households that held between 2000 and 2008 was assumed to apply out to 2035 but with manual adjustments for 2009 and 2010. Load shape information was taken into account in modelling the household electricity use.

Energy intensity data for residential (household) appliances (i.e., average annual electricity consumption for various appliances) used in Jamaica are not available and so US and Canadian energy intensity data were used as a starting point. These data were adjusted to match electricity consumption over the current account period (2000-08). Energy intensity (and activity – i.e., percentage of households with compact fluorescent bulbs) data for lighting were based on the data available from the distribution of the bulbs[15]. Data for the average annual household fuel consumption used for cooking and lighting were obtained from data provided by MEM.

Industry

Sectoral fuel use information is compiled by MEM and is available for the bauxite and alumina sector, cement, sugar and "other manufacturing". MEM provided these sectoral fuel consumption data for 2000-08. More detailed energy end use and production data were obtained from the Jamaica Bauxite Institute (JBI), Caribbean Cement Company Limited (CCCL), and the Sugar Research Institute (SIRI). Although initiatives are under way to privatise sugar estates and factories owned by the government (Sugar Company of Jamaica), no data were available for projected production for the sugar industry. Future production was assumed to remain at the 2008 levels. Energy intensity assumptions for industry are described in the following section on scenarios.

Transportation

Estimates of fuel consumption and hence GHG emissions from the road transport sector require data for the annual distance travelled (vehicle kilometres travelled or VKMT) and the emissions per kilometre for the on road fleet which is broken down into various vehicle classes. The former are the activity data and the latter the energy intensity (sometimes called emission factors).

Data for the entire fleet were obtained from Inland Revenue and data for subsets of the fleet were obtained from the Transport Authority, Jamaica Urban Transit Company (JUTC) and Montego Bay Metro (MBM). The vehicle emission rates were estimated for various vehicle classes (based on vehicle weight and fuel) using an US EPA model (MOBILE6[16]). This model uses detailed fleet information (including the age (model year), weight, fuel type, emission control technology) to estimate emission rates (in g/mile or g/km) for tailpipe, evaporative and road emissions for each of up to 26 vehicle weight/fuel classes. The MOBILE 6 emission rates for the 26 vehicle classes were consolidated into rates for 8 vehicle classes which were then used in the LEAP model together with estimated projections for the vehicle fleet. Future fleet data were estimated based on assumed levels of vehicle imports using historical import data as a guide.

Emissions from aircraft and marine vessels were based on data compiled in the GHG emissions inventory for Jamaica[17]. Aircraft emissions are those that occur during landing and takeoff (LTO) and during flights that originate and end entirely within Jamaica. LTO emissions for 2000-05 were estimated in the GHG emissions inventory[4] and projected emissions were based on the growth in air and marine traffic. The Airport Authority of Jamaica (AAJ) provided some air transport related data.

Similarly, marine emissions are those that occur when vessels ply in Jamaican waters. Fuel delivered for international flights (aviation bunkers) and international shipping (marine bunkers) are not included in emissions estimates. Limited fuel use data were available for domestic marine travel and this sub-branch was not included separately. The fuel consumption for domestic marine travel is small and would be included in other branches.

Government

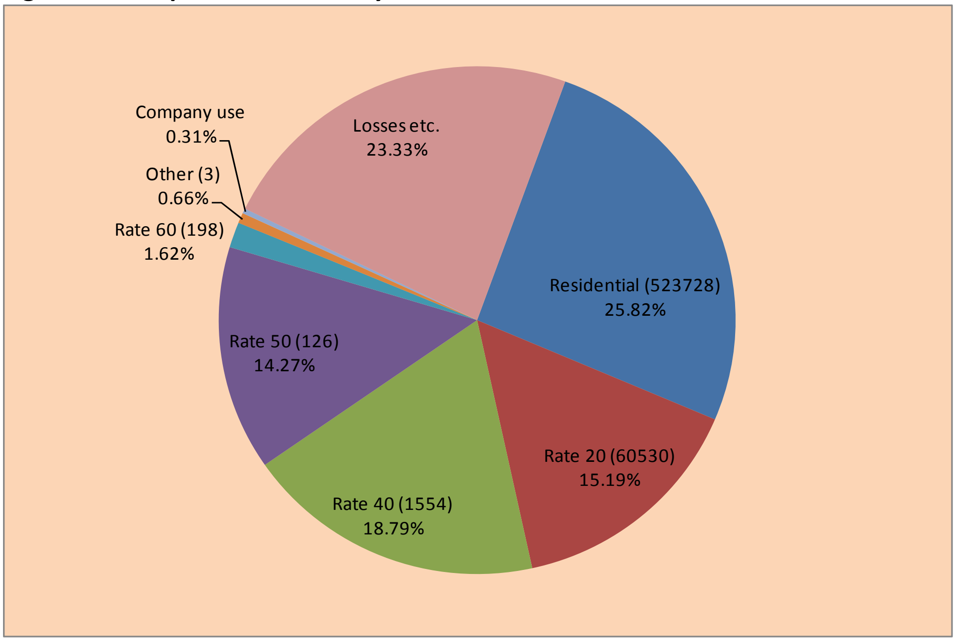
Since data for fuel and electricity consumption by government agencies are available, the Government branch was included. Electricity consumption and fuel use data were obtained from the MEM and from National Water Commission (NWC) annual reports. The government sector was broken down into NWC, hospitals and "other government" since, for the first two branches especially, extensive audit data are available and mitigation proposals for hospitals (fuel end electricity conservation) and NWC are planned. The hospital audits[18] included several groupings of energy conservation measures which were grouped together to define mitigation measures for scenarios that were developed.

Other Electricity Branches

Electricity consumption information is available for the rate classes used by JPS (Rates 20, 40 and 50 and 60 and "Other") and so these rate classes were used in the mitigation assessment. Care was taken to avoid double counting where separate electricity consumption data were available (e.g., cement, petroleum refining, NWC, government). The recent JPS Rate Application[19] and ESSJ publications provided data on the numbers of customers in each rate class, the load shape and the annual electricity use for all rate classes. Week day/weekend load shape information for all rate classes available in the JPS Rate application was used in modelling the electricity demand.

The disposal of electricity in 2008 (percentages of total GWh for various rate classes, losses and company use) is shown in Figure 3.5. The numbers in parentheses after the rate classes are the numbers of customers in the rate class. The Rate 40 and Rate 50 customers accounted for 33.3 percent of the total electricity disposal with only 1680 customers: this is compared to the residential rate class (Rate 10) which accounted for 25.8 percent of the electricity disposal.

Figure 3.5: Disposal of Electricity in 2008



Unfortunately, information on the types of equipment (or other information such as a Jamaica industrial classification code) used by the Rate 40 and Rate 50 customers, which could allow similar analysis to that for the residential customers, is not available. Information and data on recently completed and planned energy conservation measures for one Rate 50 customer (UWI) was provided and it illustrated the potential for energy conservation (mitigation). However, as UWI might not be representative of the average Rate 50 customer, less aggressive mitigation measures were applied for these customers.

Transformation

The transformation module comprises petroleum refining, electricity distribution and generation, charcoal production and coal gasification branches. Electricity transmission and generation data were obtained primarily from the publicly available March 2009 JPS 2009-14 Tariff Rate Application that was available on the web site of the Office of Utility Regulation (OUR) and from historical JPS reports provided by OUR. Petrojam provided data for the Refinery and charcoal data were derived from ESSJ and MEM reports. Coal gasification was included since syngas from gasified coal is an option for use in alumina kilns. Additional details on the transformation are provided in the section on scenarios.

Resources

Indigenous energy resources are limited to hydropower; solar, wind, biomass (bagasse, fuel wood, charcoal) and peat, since there are no known petroleum or coal resources.

Hydropower: There are currently (2008) 23.1 megawatts (MW) of installed hydropower at eight locations. Additional hydropower generation capacity is planned.

Biomass: Bagasse, which is a fibre residue from sugar cane milling, is the largest indigenous renewable energy resource. Current use in boilers at sugar factories is not optimal due to irregular or insufficient cane supply and inefficient boiler equipment at the majority of sugar factories. Additional utilisation of biomass is planned.

Firewood and Charcoal: Charcoal and fuel wood are used primarily in the residential sector as fuel for cooking. There is also commercial use of charcoal for cooking especially in roadside establishments. Fuel wood (bamboo and acacia, leucaenea) has been used at one sugar factory and also at one lime kiln. Except for fuel wood use in the sugar industry, the estimates of fuel wood and charcoal use are subject to large uncertainties.

Biogas: Generation of biogas from agricultural and farming operations has been limited. In 2000, there were about 120 biogas generators based on agricultural wastes (e.g., pig or chicken farm wastes) or domestic sewage. The energy supplied by each of these systems was about 37 GJ/year based on gas production of 4.5m^3/day (65% methane). Many of the residential owners of biogas use the system for all of their energy (cooking, refrigeration and lighting) needs. The overall potential for biogas production in Jamaica has been estimated at 20 million m^3/year (equivalent to 75,000 bbl oil). The potential for further exploitation of biogas is attractive especially in remote/low population density areas where costs for electricity transmission lines are not cost effective.

Peat: There are limited amounts of peat located near the Negril and Black River areas. Estimates of deposits are approximately 20 million metric tonnes, but exploitation of peat resources has been ruled out primarily because of the adverse environmental impacts since the deposits are located in areas that are ecologically sensitive and are dependent on tourism.

Wind: As of 2008, there was a 20 MW facility at Wigton and a 0.225 MW wind turbine at Munro College. Additional wind farms are planned but additional mapping is to be undertaken to help determine the additional potential for wind energy [total wind energy potential is estimated at 45-70 MW][20].

Solar: Given Jamaica's tropical location, solar energy potential for a wide range of applications is excellent. There is limited use of solar crop drying or water heating, but additional solar water heating systems are planned for hospitals. Expanded use of solar water heating, for example in hotels, would reduce the need for energy derived from fossil fuel combustion. As of 2009, there was not any consideration in Jamaica of solar technologies for solar cooling or power generation.

Other Alternate Energy Sources: Currently there are very limited applications of photovoltaic (PV) systems but additional PV systems are contemplated. The siting of a demonstration Ocean Thermal Energy Conversion (OTEC) plant to produce electricity (e.g., a 15 MW plant) has been under investigation for some time, but the prospects do not warrant including OTEC as a source of electricity in any scenario. A waste-to-energy project is contemplated.

Non-Energy Sector Effects

The non-energy sector effects included were CO_2 emissions from cement and lime manufacture and from proposed electricity generation using Petroleum coke. Other GHG emissions from agriculture, forestry and industry were based on projections from the 2000-05 GHG emissions inventory except in cases where data from specific projects were available. These included rice farming, reduction ion deforestation rates, and replacement of HFC refrigerants by hydrocarbon refrigerants.

3.2.2 Scenarios

Three scenarios were developed to project emissions – a **Reference Scenario (Ref)** and **Scenarios 2 (*S2*)** and **3 (*S3*)** which were characterised primarily by different rates of growth for the population and GDP.

The Reference Scenario is linked to the Vision 2030 GDP and population growth targets, and does not include any initiatives to mitigate GHG emissions. The Reference Scenario assumes that two of three alumina refineries that closed in 2009 (Alumina Partners and Windalco Ewarton) would reopen and that there would be continued use of oil at alumina plants. It also assumes that the Petrojam Refinery Upgrade would be completed in 2014 and would provide low sulphur diesel and gasoline for the vehicle fleet and petcoke for a 100 MW plant at Hunts Bay. Finally, the Reference Scenario also assumes the use of coal at the new old Harbour power station.

S2 and *S3* assume progressively higher GDP growth rates but lower population growth rates. Both *S2* and *S3* include mitigation options. For S2 and S3, there are choices for fuels (coal, heavy fuel oil, diesel oil, natural gas, and gasified coal (Syngas) that can be used for the various processes. Also included in S3 is an option for the use of nuclear power as noted in the energy policy. Future energy intensity data used in scenarios *S2* and *S3* were based on existing and proposed voluntary energy standards for the appliances used in the US and/or Canadian Energy Star programs, but with later implementation or penetration for Jamaica. Import data for various appliances and the typical and maximum lifetimes of appliances together with policy initiatives were taken into consideration in estimating the penetration of energy efficient appliances in scenarios *S2* and *S3*.

The fuel choices for various demand and transformation processes are indicated in Table 3.5.

Table 3.5: Fuel Choices for Various Demand and Transformation Processes

Process	HFO	Diesel	Coal	Natural Gas	Syngas	Nuclear
Bayer process boilers and lime kilns (Bayer/Lime kilns), new steam boilers	√		√	√		√[#]
Slow/Medium speed diesel engines	√			√		
Alumina kilns	√			√	√	
Gas turbines		√		√		
Boilers at existing steam fired electricity generating stations	√					

[#] considered only as an option in Scenario 3 – see text

The feasible combinations of processes and fuels led to the options within Scenarios 2 and 3 (see Table 3.6) since the possible combinations are limited by the following conditions and assumptions:

- Once introduced, coal or natural gas is used in all possible processes except as noted below;
- Alumina kilns may not use coal (hence the use of syngas from gasified coal). Syngas would be introduced at Alpart and Windalco in 2015 and at Jamalco in 2013;
- Existing heavy fuel oil fired boilers and slow speed engines at electricity generating stations would be retrofitted to burn natural gas;
- Bayer process boilers would burn oil up to 2013 and be upgraded/retrofitted to use natural gas or coal after 2013 (coal or gas at Windalco in 2015; coal at Alpart in 2015);
- Existing and new medium/slow speed engines retrofitted could use natural gas;
- The new alumina plant (Scenario 3 only) would use either natural gas or coal with gasified coal in the alumina kiln;
- Included are coal or natural gas fired power generation at some alumina plants and/or at the cement company;
- The addition of a nuclear power (in the event that nuclear power generation becomes economically and otherwise (e.g., human resource, logistics etc.) feasible is included as an option that entails the use of natural gas for other purposes (although it could be combined with other fuels used elsewhere); and
- When natural gas is available, it would be used in some of the vehicle fleet.

Highlights of the process and fuel combinations are indicated in Table 3.6. Note that although a scenario (designated as *S2* Oil in Table 3.6) that would entail continued exclusive use of oil (similar to the reference scenario) is possible, it would not sufficiently diversify the fuel supply and also would not be economically viable for the bauxite, alumina and power generation sectors. Because of these factors, the scenario option *S2* Oil was not included in the mitigation assessment.

Table 3.6: Process and Fuel Combinations for Potential Scenario Options

Scenario	Bayer/Lime Kilns/ New Steam	Slow Speed Engine Existing/New	Al Kilns Existing / New[#]	Gas Turbines	Existing Steam Plants
Reference Scenario					
Ref	Current use	Current use	Current use	Current use	Current use
Scenario 2 Options					
S2	Coal Jamalco 2013 Alpart 2015 Windalco 2015 JPS Old Harbour	HFO/HFO	HFO	Diesel oil	HFO
S2 Oil	HFO	HFO	HFO	Diesel oil	HFO
S2 SYN	Coal Jamalco 2013 Alpart 2015 Windalco 2015	HFO	Syngas Retrofit Jamalco 2013 Alpart 2015 Windalco 2015	Diesel oil	HFO
*S2*NG	NG Jamalco 2013 Alpart 2013 Windalco 2015 JPS (Except Hunts Bay)	NG retrofit/ NG	NG retrofit Jamalco 2013 Alpart 2013 Windalco 2015	NG JPS (Except Hunts Bay)	HFO
Scenario 3 Options					
S3	Coal Jamalco 2013 Alpart 2015 Windalco 2015 JPS Old Harbour	HFO	HFO/Syngas	Diesel oil	HFO
S3 SYN	Coal Jamalco 2013 Alpart 2015 Windalco 2015	HFO	Syngas Retrofit/Syngas Jamalco 2013 Alpart 2015 Windalco 2015	Diesel oil	HFO
S3 NG	NG Jamalco 2013 Alpart 2013 Windalco 2015 JPS (Except Hunts Bay)	NG retrofit/NG	HFO/Syngas	NG	HFO
*S3 NG*NU	Coal Jamalco 2013 Alpart 2015 Windalco 2015 JPS Old Harbour Nuclear after 2020	NG retrofit/NG	HFO/Syngas	NG	HFO

[#] Note: New alumina kiln on *S3* only

Highlights of the main scenarios

Reference Scenario (Ref)

Only one option was considered – namely the continued use of fuels in all existing processes. This scenario also assumes completion of the Petrojam Refinery upgrade in 2014 and that low sulphur gasoline and diesel will be available for the on road vehicle fleet.

Although the Reference Scenario does not include any mitigation measures beyond those that are currently in place, the upgrading of the Petrojam refinery and the reopening of two alumina plants have been included that imply certain mitigation measures as follows:

- The refinery upgrade will entail provision of low sulphur diesel and gasoline which will affect the emission rates for vehicles.
- The reopening of the Alpart plant is assumed to entail improvement in the energy efficiency of the Bayer process. (Additional improvements in energy efficiency of the Bayer process at all alumina plants are indicated in Scenarios 2 and 3.)
- The construction of a new kiln and cement mills at the cement company resulted in significant energy intensity improvements. In all scenarios it was assumed that kiln 4 which was closed in 2008 would reopen with improved energy efficiency in 2011. Because of this further energy intensity improvements for the cement industry are negligible.

Scenario 2 (S2)

S2 assumes a lower population growth rate and higher GDP growth rate than the Reference Scenario. It also includes added alumina production capacity. The main option designated as *S2* has coal as the fuel for the Bayer processes, lime kilns, and a new coal fired station at Old Harbour, and no natural gas. The main mitigation option in this scenario (designated as *S2 NG*) entails the use of compressed natural gas for the Bayer process (instead of oil in the reference scenario), lime kilns, and electricity generation at the Bogue generating station (instead of diesel), and for the new Old Harbour generating station (300 MW) (instead of coal). Existing slow or medium speed diesel engines currently using heavy fuel oil would be retrofitted to use natural gas. Other mitigation measures include Bayer process energy efficiency improvements, the use of more efficient household appliances (lighting, refrigerators), use of compressed natural gas in some of the vehicle fleet and improved energy efficiency in the government sector (hospitals, NWC and the remainder of the government sector). Although the mitigation measures in the government sector are small relative to the total demand, the reductions have been demonstrated to be cost effective. The same is true of lighting and air conditioning initiatives at UWI.

Scenario 3 (S3)

S3 assumes a lower population growth (and hence lower household electricity demand) and a higher GDP growth rate than for *S2* and a more rapid decrease in the number of persons per household. *S3* includes all of the *S2* and *S2 NG* initiatives as well as additional energy intensity reductions at two alumina plants. The mitigation measures, however, are offset by the increased energy requirements and emissions from the proposed addition of a new alumina plant. The introduction of additional hydro generation capacity would contribute to lower emissions. An option entailing nuclear power along with natural gas is included. Under this option, the nuclear power plant would be added instead of power stations at bauxite alumina plants or the cement company.

Some of the main features of the scenarios are highlighted below. More detailed summaries of the scenarios are provided in Appendices 3.1 and 3.2. Most, if not all, of the mitigation activities and projects for the addition of generation capacity were based on a detailed list of energy related policies, measures, and projects compiled by MEM (Appendix 3.3).

Key Parameters

For the Reference Scenario, the GDP growth rates and population projections are the same as those included in Vision 2030 Jamaica.

The GDP growth rate for the Reference Scenario was assumed to increase to 4 percent by 2015 and remain constant at 4 percent up to 2035. For S2 and S3 respectively, GDP growth is assumed to be the same as the Reference Scenario up to 2015 and thereafter increase to 4.5 percent and 5 percent in 2035.

Population growth rates are based on the achievement of targets set in the Population Sector Plan under Vision 2030 Jamaica (0.25% and 0% for S2 and S3 respectively). Household size was assumed to decline from 3.33 in 2008 to 3.20 in 2015 to 3.15 in 2035 (S2) or to 3.20 in 2015 then to 3.10 in 2035 (3). The number of households, as determined by population growth and household size, largely determined household demand.

Demand

Growth rates in electricity consumption from 2009-14 were estimated in the JPS rate application and used in all scenarios. After 2014, increasingly optimistic growth rates were used.

For the bauxite and alumina sector, it was assumed that two plants that closed in 2009 would reopen in 2012 in all scenarios. The introduction of natural gas was assumed only to occur in S2 together with capacity expansions at Ewarton and Jamalco. S3 would see the introduction of a new alumina plant in 2015. Bauxite mining, kiln drying, and lime production were linked to alumina production. Energy use for bauxite mining included rail transportation since data were not always reliably disaggregated to delineate fuel used for rail transportation (which is used only in the bauxite alumina sector) from the fuel used for other bauxite and limestone mining activities. Cement production was assumed to increase as a percentage of the GDP growth rate (i.e., 30% for Reference, 35% for *S2* and 45% for *S3*).

Activity data for transport (vehicle fleet) were based on assumptions for the growth and age distribution of the fleet. Various approaches were considered in making estimates of the growth in the vehicle fleet. From 2000-08, the percentage of households owning vehicles increased from 15.0 percent to 20.3 percent in 2006 and then decreased somewhat to 19.3 percent in 2007. The number of motor cars in 2000, 2005, and 2008 were respectively 270,005, 355,091 and 408,264 – an average annual increase of 6.3 percent between 2000 and 2005 and 5 percent between 2005 and 2008. These trends illustrate how challenging it is to estimate the future growth in the vehicle fleet, especially when compounded by the volatility in the prices of gasoline and vehicles as a result of devaluation of the Jamaican dollar and the global increase in fuel prices as well as likely changes in consumer preferences (e.g., switch from SUVs to smaller, more fuel efficient vehicles).

In the absence of more definitive projections, it was assumed that the fleet would continue to grow based on the trends from 2000-08. The annual vehicle sales for each vehicle weight class were assumed to be in the same proportion as the weight class distribution for the fleet in 2008.

Transformation

Historical data on losses in electricity distribution and JPS projections from 2009-14 for reduction in these losses were used in all scenarios. In all scenarios, the upgrading of the Petrojam refinery was assumed. The “own use” energy and the slate of products after the upgrade were provided by Petrojam. Electricity generation projections were based on characteristics of individual thermal and wind units and on collective hydro generating stations. Additions and retirements of generating capacity were based on the addition of individual units. Projections from 2009-14 in all scenarios were based on the changes indicated in the recent JPS rate application.

After 2014, the reference scenario assumed coal and Pet Coke as the fuels used for added capacity, together with wind stations to meet the goals in the Energy Policy. Compressed Natural Gas as a fuel was assumed in S2 and S3 and a nuclear option was included in Scenario 3.

Coal gasification and charcoal conversion data were obtained from the literature[21]. Historical charcoal production data are notoriously subject to considerable uncertainty. The historical charcoal consumption data between 2000-05 were adjusted downwards based on estimates of residential charcoal use derived from the percentage of households using charcoal for cooking and estimates of the energy required for cooking and an arbitrary estimate of the amount of charcoal used in commercial activities. These estimates were equivalent to wood removal rates about 30 percent higher than those used in the GHG inventory. This corresponds to 0.13 percent of disturbed forest versus 0.1 percent of disturbed forest in the GHG inventory. It must be stressed that these estimates are also subject to uncertainty and point to the need for better estimates for charcoal production and consumption.

3.3.3 Results

LEAP allows presentation of the emissions either a) where they occur (i.e., demand, transformation and non-energy sector effects) or b) by allocating the emissions in the transformation categories back to the demand source. The second approach provides the so-called final energy demand (or final environmental loadings). The non-energy sector emissions are those associated with the chemical transformation of limestone into lime (which releases CO_2) or in landfill emissions (releases CH_4 and CO_2) or in the release of CO_2, CH_4 and N_2O from the agriculture and forestry sectors.

The presentation of the environmental loadings for all three scenario projections in this assessment includes the current account period (2000-08) so that comparisons can be made with the GHG emissions inventory and/or energy consumption over this period.

Energy Balance

LEAP's outputs include annual energy balances. The results for 2000 and 2008 are shown in Figures 3.6 and 3.7.

Figure 3.6: Energy Balance for Jamaica (2000)

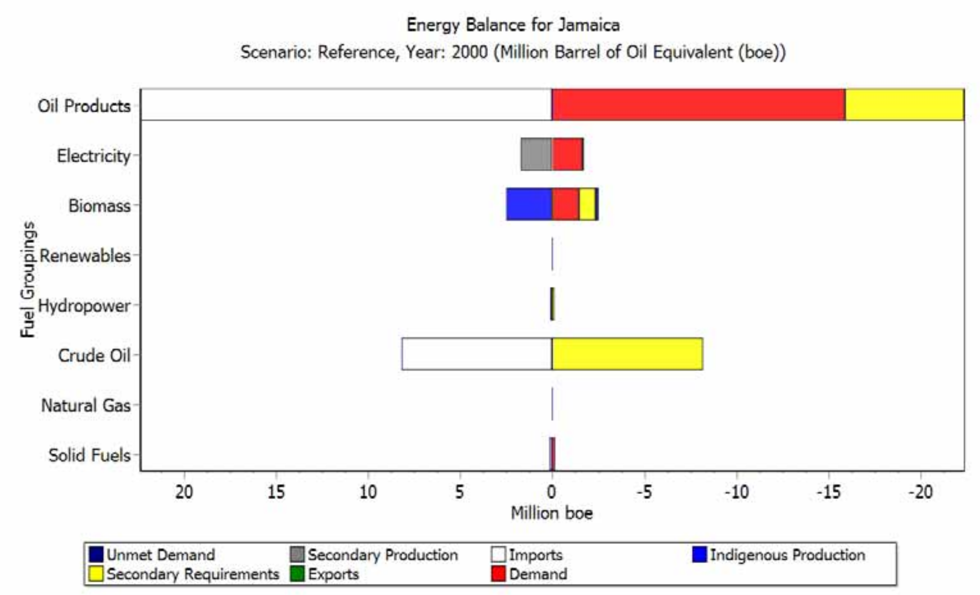
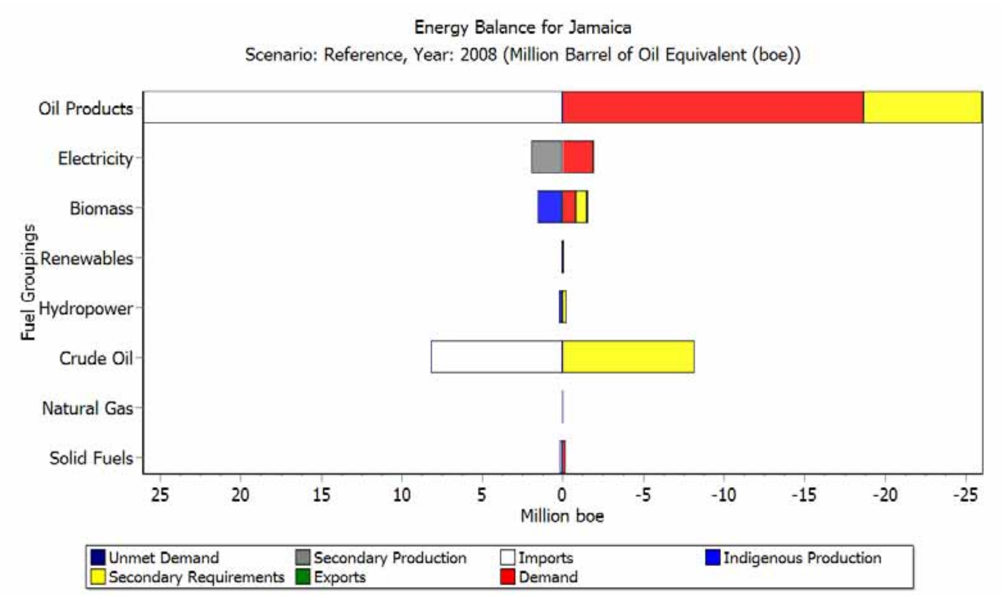


Figure 3.7: Energy Balance for Jamaica (2008)



Final Energy Demand (Environmental Loadings)

The final environmental loadings of CO_2, N_2O and CH_4 for all scenarios are shown in Figures 3.8 to 3.10. The most striking element of all scenario projections is the decrease in emissions from 2009-11. This is due to the closure of three alumina plants in the first quarter of 2009 and the (assumed) reopening of two of those plants in 2011 with full production achieved in 2012.

Figure3.8: Final Environmental Loading for CO_2 for Jamaica, All Scenarios (2009-35)

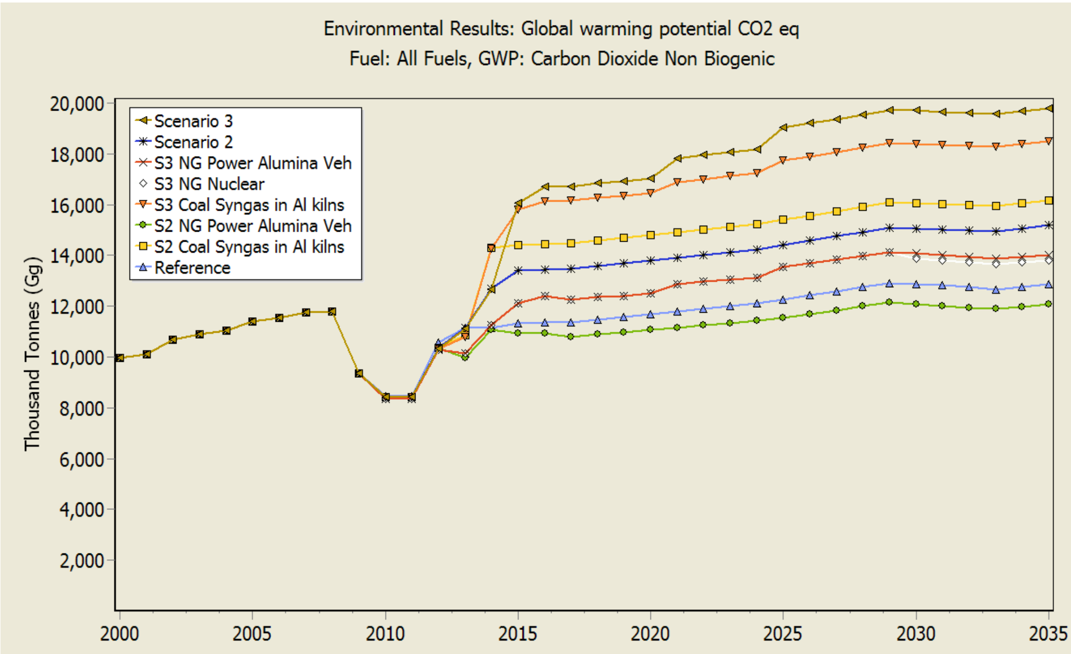


Figure 3.9: Final Environmental Loading for N_2O for Jamaica, All Scenarios (2009-35)

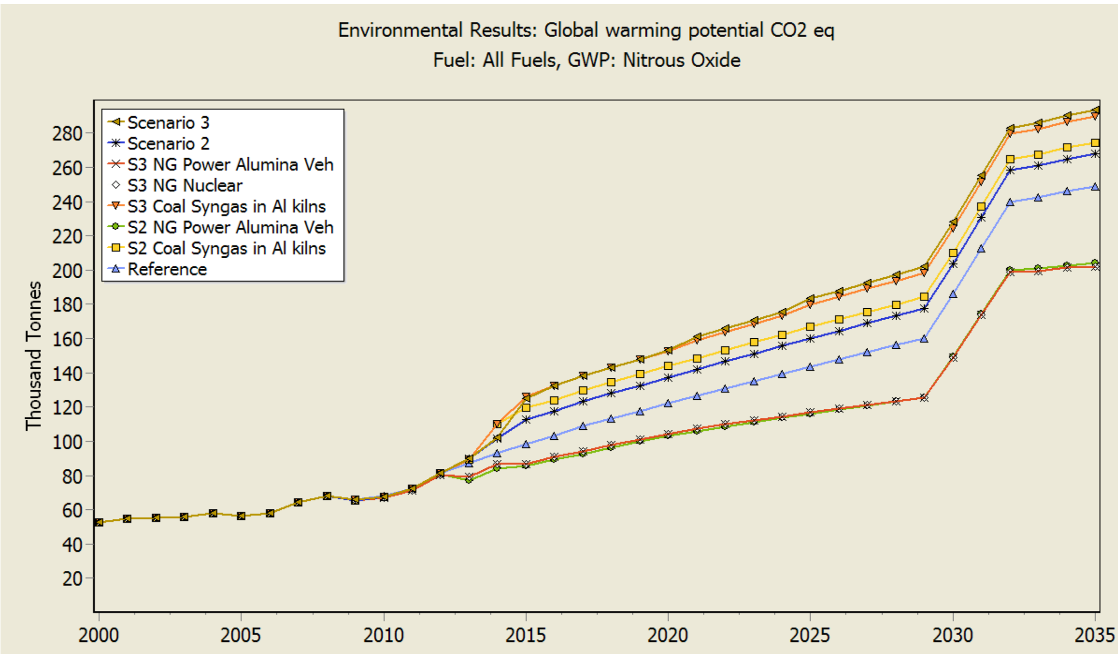
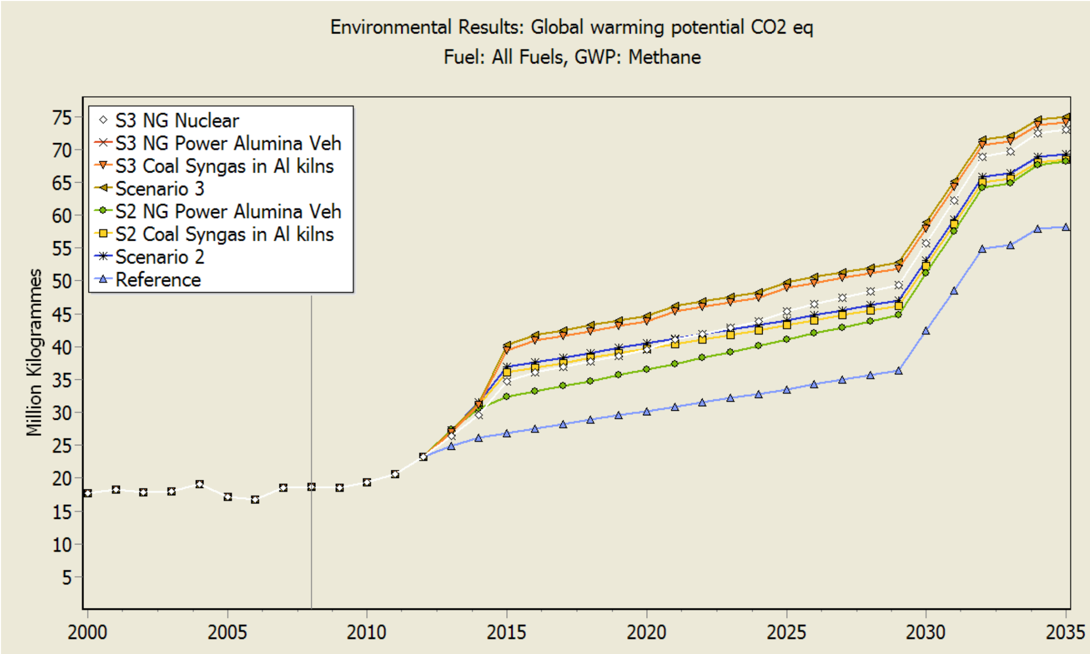


Figure 3.10: Final Environmental Loading for CH_4 for Jamaica, All Scenarios (2009-35)



For CH_4 and N_2O, the Reference scenario emissions are generally lowest – due to the low production levels relative to the other scenarios. The *S3* emissions are the highest because of the use of coal where feasible; the emission factors for coal are higher than for oil or natural gas. In the case of CO_2, the pattern is similar except that the use of natural gas in *S2 NG* results in CO_2 emissions that are slightly lower than the Reference scenario.

The *S3 NG* and *S2 NG* emissions are consistently lower than the corresponding *S3* or *S3* emissions and reflect the lower emission factors when natural gas is used (compared with coal or coal and syngas in alumina kilns).

The combined energy and non-energy CO_2 emissions are shown in Figure 3.11 while the non-energy CO_2 emissions alone are shown in Figure 3.12. The latter figure illustrates the impact of the use of petcoke starting in 2013. Use of petcoke for power generation entails using limestone to remove SO_2 and that process will release additional CO_2 from the limestone.

Figure 3.11: Final Environmental Loading for CO_2 (Biogenic and Non-Biogenic) for Jamaica, All Scenarios (2009-35)

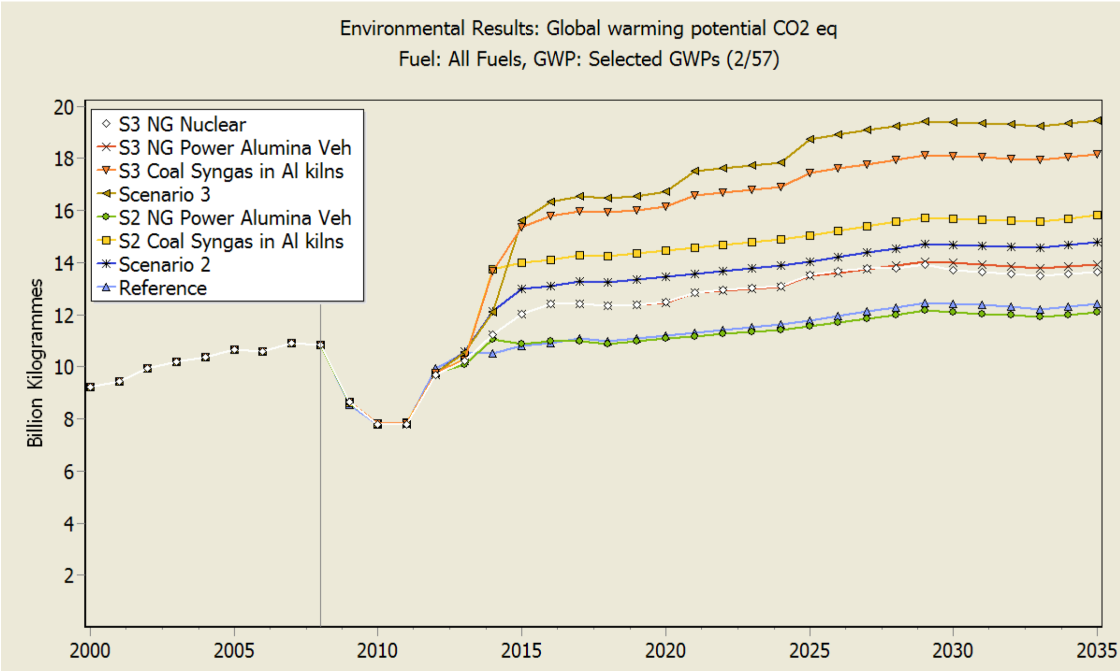
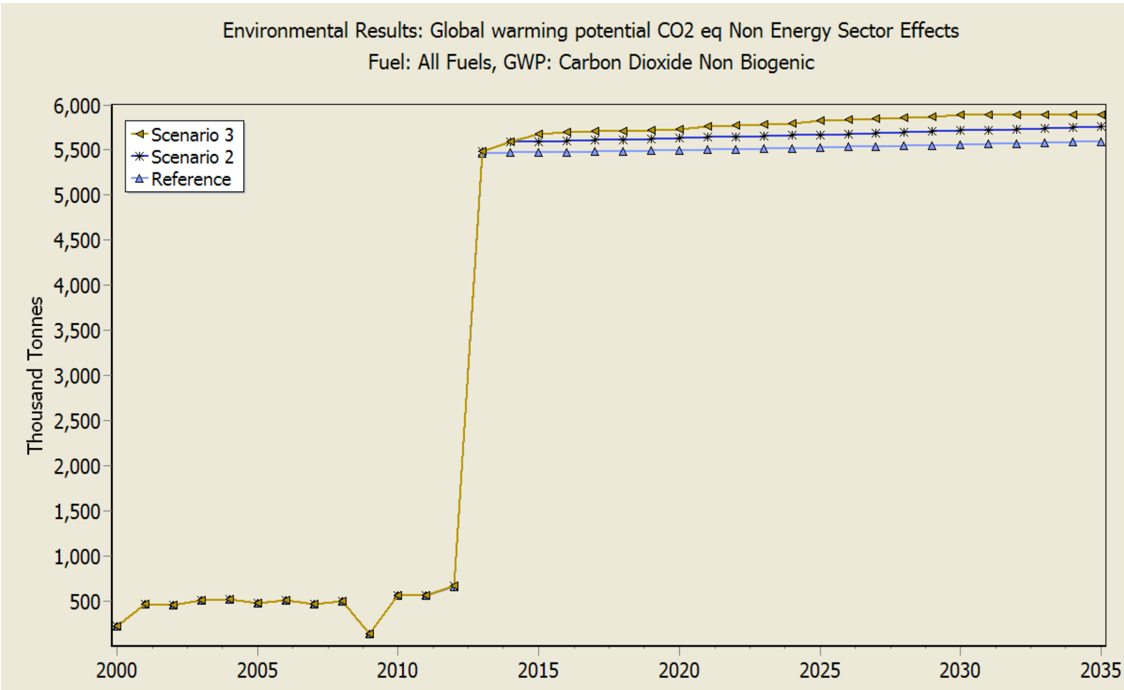


Figure 3.12: Final Environmental Loading for CO_2 from Non-Energy Sector Effects for Jamaica (2009-35)



The most dramatic effect of the use of natural gas is seen in the SO_2 emissions for the various scenarios. Figure 3.13 shows SO_2 emissions from demand sources while Figure 3.14 shows for SO_2 emissions from all transformation sources, that is, oil refining, electricity generation, charcoal making and coal gasification. The *S2 NG*, *S3 NG* and *S3 NGU* emissions are considerably lower than the corresponding *S2* or *S2* Coal/Syngas and *S3* and *S3* Coal/Syngas emissions.

Figure 3.13: Final Environmental Loading for SO_2 from Demand Sources for Jamaica (2009-35)

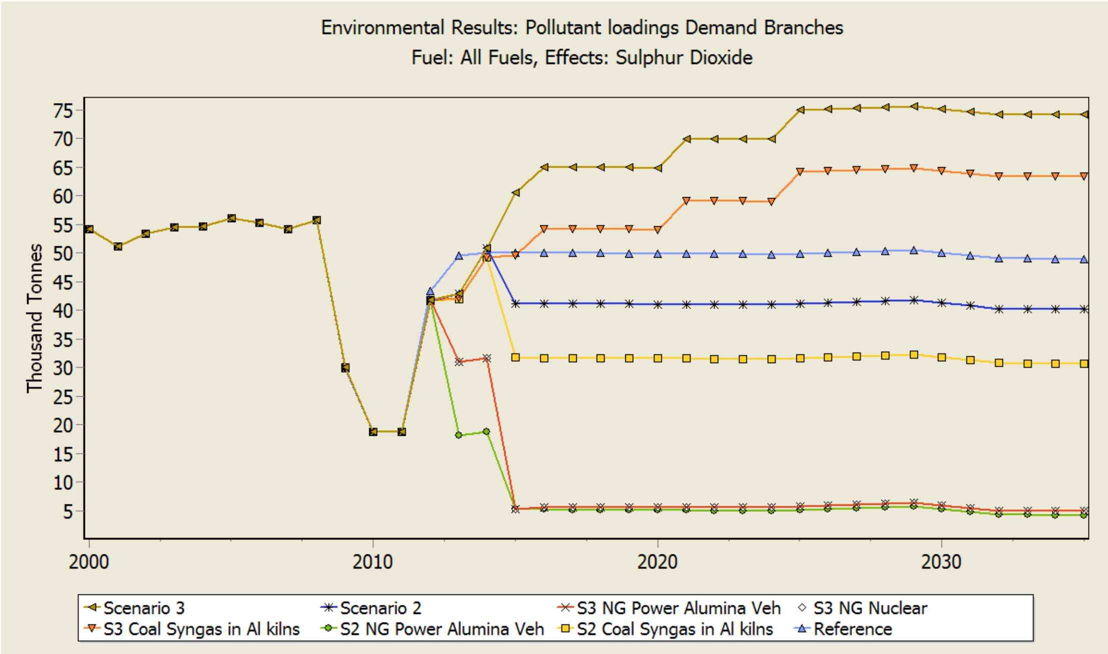
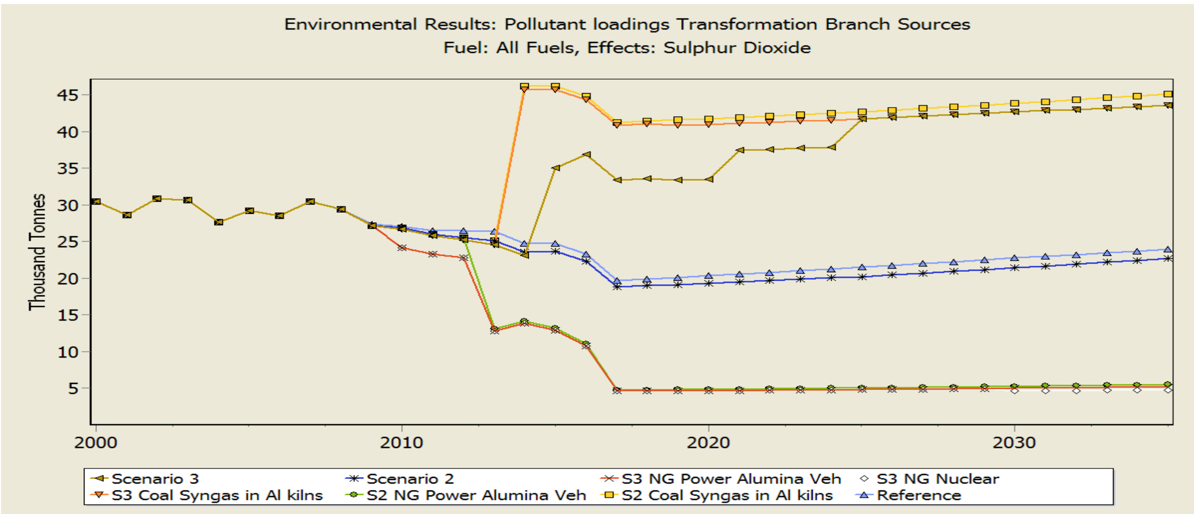
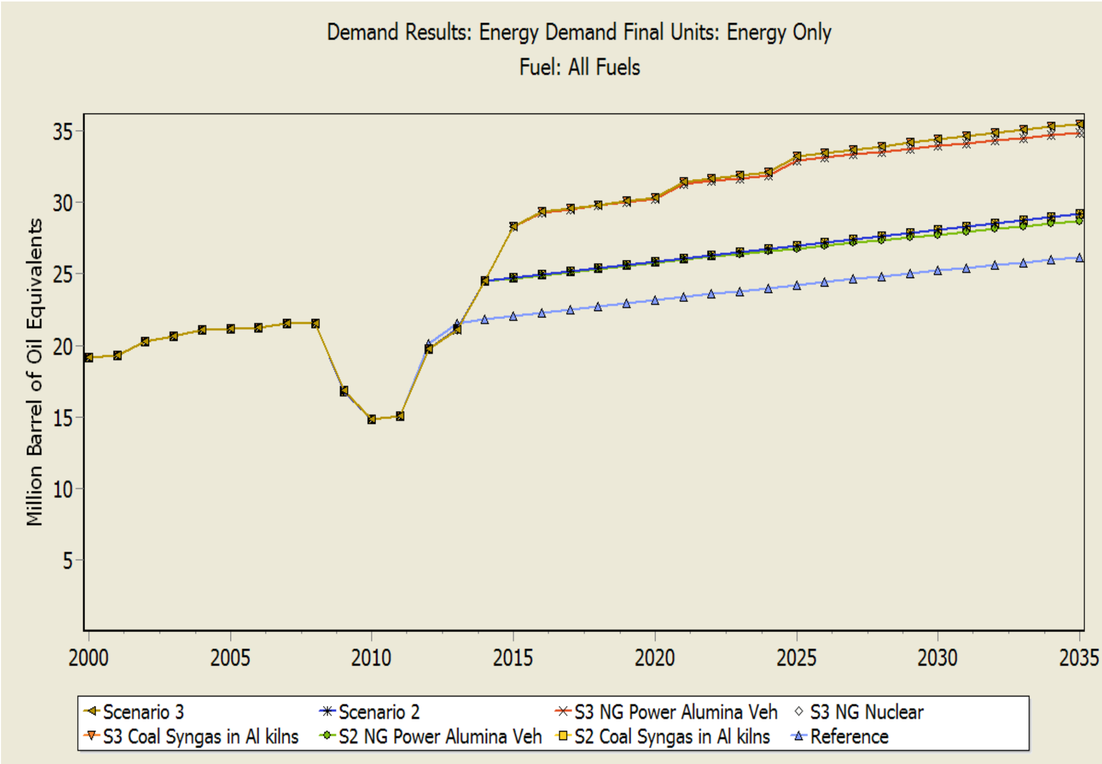


Figure 3.14: Final Environmental Loading for SO_2 from Transformation Sources for Jamaica (2009-35)



The final energy demand for all scenarios is shown in Figure 3.15. As with the environmental loadings, the most striking feature is the dramatic declines in energy demand in 2009 through 2012 as a consequence of alumina plant closures. The final energy demand is not very dependent on the choice of fuel in the *S2* and *S3* scenario options and the demand for *S2* options are grouped together lower than the grouping for the *S3* options. The large increase in energy demand in the *S3* options is due mainly to the new alumina plant which is included only in *S3* options and to lesser extents on lower population growth (but this is mediated by lower persons/household) and the associated demands for electricity and on the increase in cement production.

Figure 3.15: Final Energy Demand Projections for Jamaica, All Scenarios (2009-35)



Energy Transformation Projections

Transformation includes electricity generation, petroleum refining, coal gasification and charcoal production. No change in petroleum refining capacity after the Petrojam refinery upgrade is anticipated although the refinery will be able to vary the output to meet demands. The data for charcoal production are uncertain and it is expected that demand for charcoal will fall as fewer households use charcoal and its use is discouraged.

The changes in total electrical generating capacity in all scenarios to meet energy demands are shown in Figure 3.16 – noting that added capacity was not optimised.

Gasification outputs will be used only to meet the demands for calcining alumina only when coal is used in the Bayer process. The gasification requirements for all scenarios (*S2 SYN* and *S3 SYN*) are shown in Figure 3.17.

Figure 3.16: Electricity Generating Capacities for Jamaica, All Scenarios (2009-35)

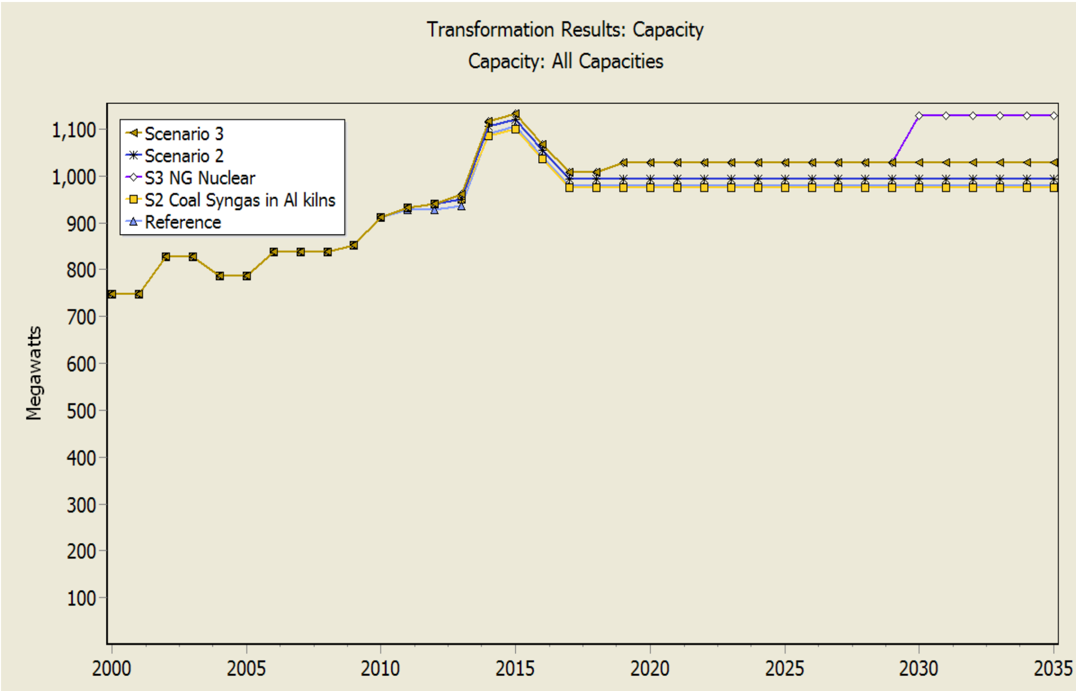
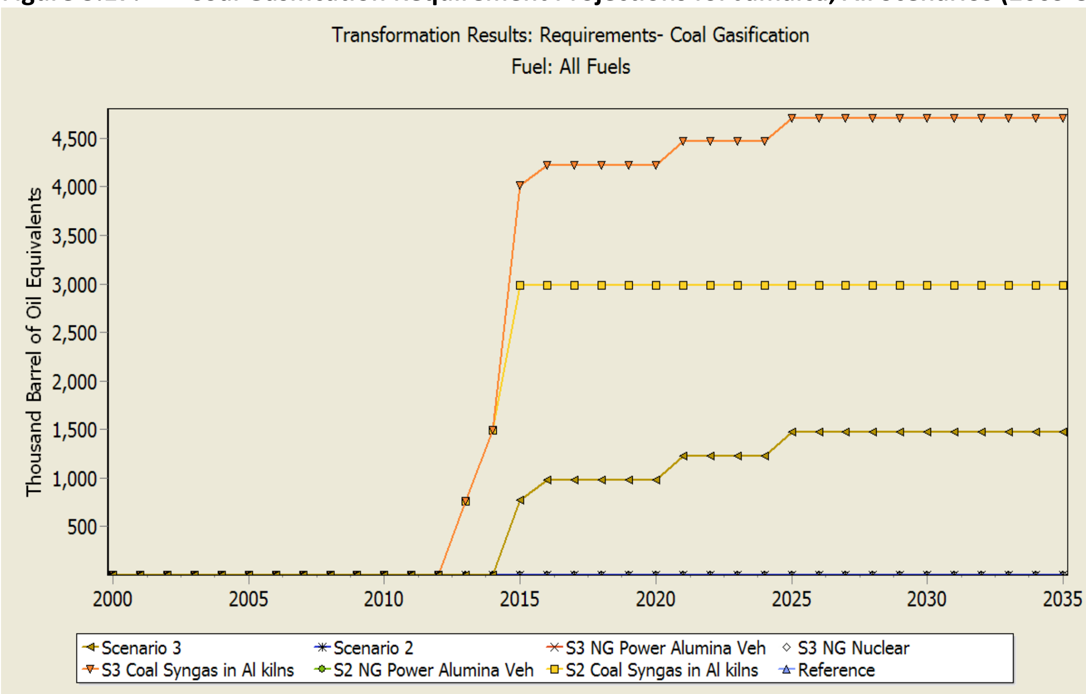


Figure 3.17: Coal Gasification Requirement Projections for Jamaica, All Scenarios (2009-35)



Detailed Analysis of Environmental Loadings and Energy Demands

The environmental loadings and energy demands for selected demand, transformation, and non-energy sub-sectors are described further to illustrate the impacts of various projects and mitigation measures. The environmental loadings refer to where they occur (since the transformation loadings will be presented separately) and focus on CO_2, since nearly all mitigation measures are directed at energy conservation or fuel substitution which directly affect CO_2 emissions and their impact on other pollutants (except for SO_2) is less dramatic.

The examples selected for illustration are those where there are significant mitigation measures in scenarios *S2* and *S3.* Hence, cement and sugar manufacturing and the "Other Manufacturing" areas which have no significant mitigation measures are not included. In the case of the sugar industry, the exclusion is based not on the need or opportunity for mitigation measures, but rather on the lack of information. Significant mitigation measures have already been implemented by the cement industry and are thus included in the Reference scenario. Hence, there are nominal cement industry related changes in *S2* and *S3* scenarios that can be attributed to mitigation.

Industrial

The industrial sectors considered were:

- Bayer processing;
- Alumina kilns;
- Bauxite mining;
- Lime kilns.

The CO_2 emissions for all scenarios for these activities are shown in Figures 3.18 to 3.21. In all cases the emissions are dictated by the alumina production levels but the impacts of using natural gas are evident in *S2 NG* and *S3 NG* relative to *S2* and *S3* (which respectively have the same alumina production levels but use coal). Since there are no fuel choices for bauxite mining, the CO_2 emissions are determined only by the alumina production levels (which are directly related to the amount of bauxite mined).

Figure 3.18: CO_2 Emissions from Bayer Process for Jamaica, All Scenarios (2009-35)

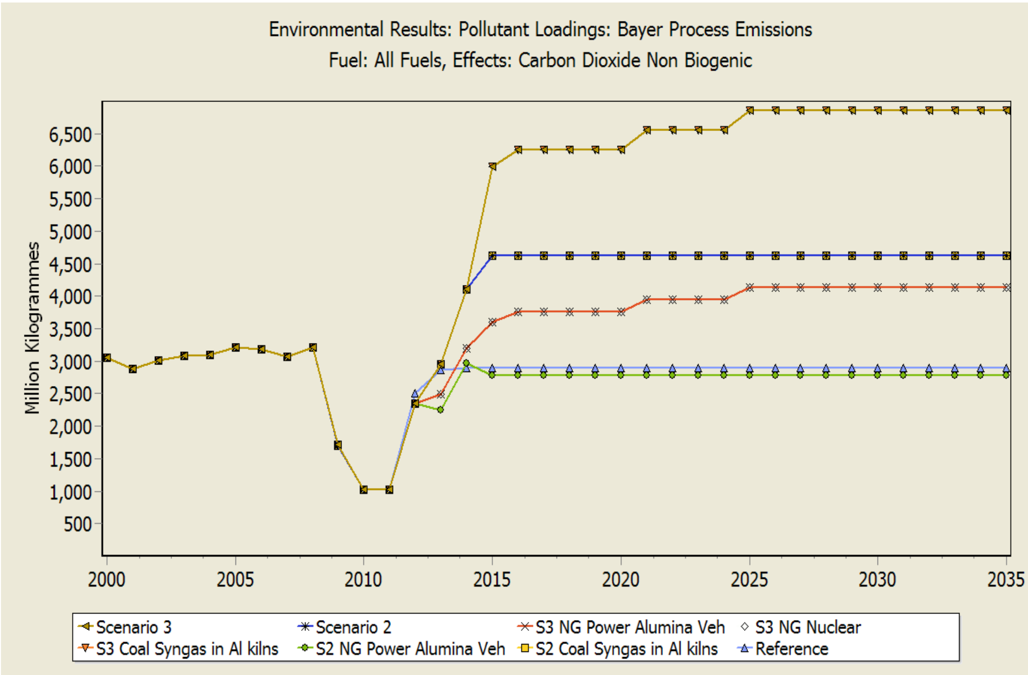


Figure 3.19: CO_2 Emissions from Alumina Kilns for Jamaica, All Scenarios (2009-35)

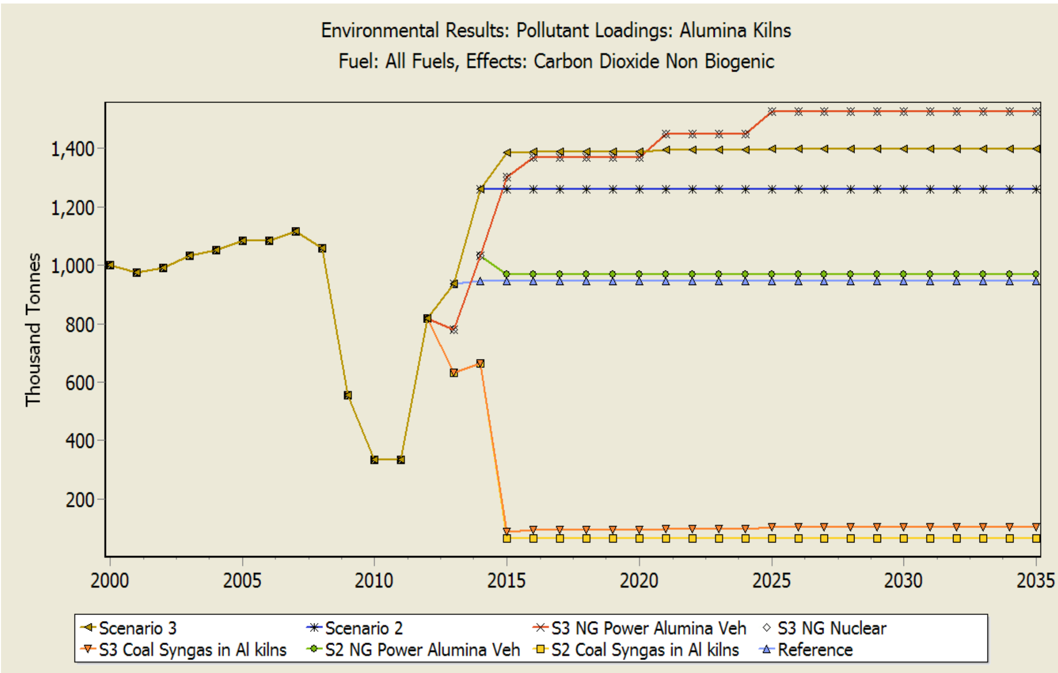


Figure 3.20: CO_2 Emissions from Lime Kilns for Jamaica, All Scenarios (2009-35)

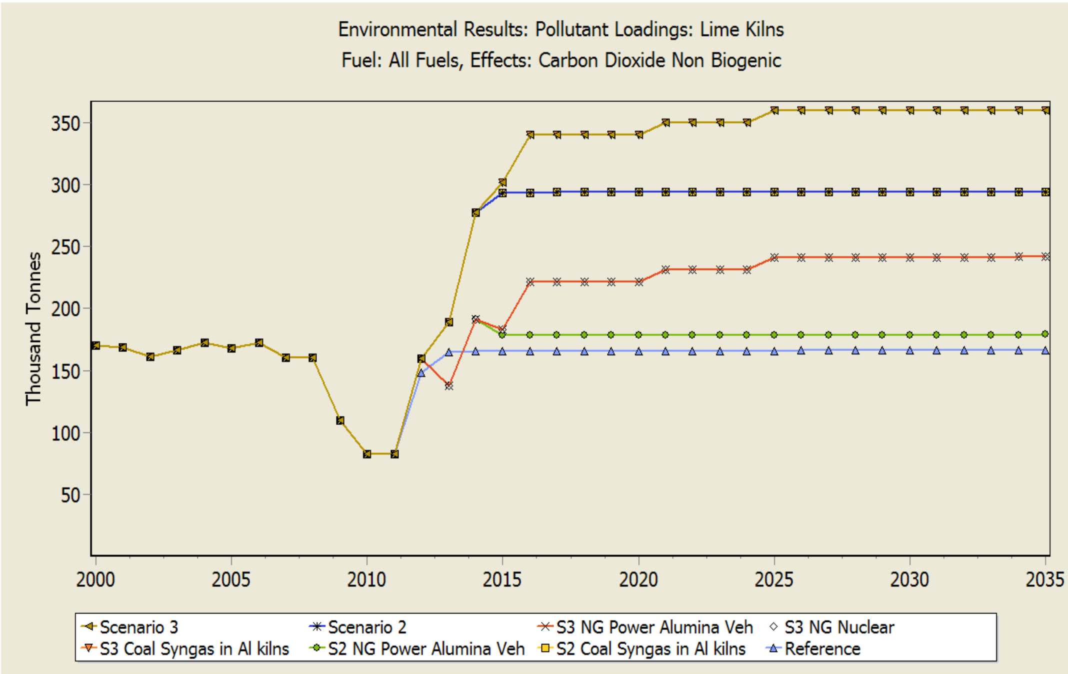
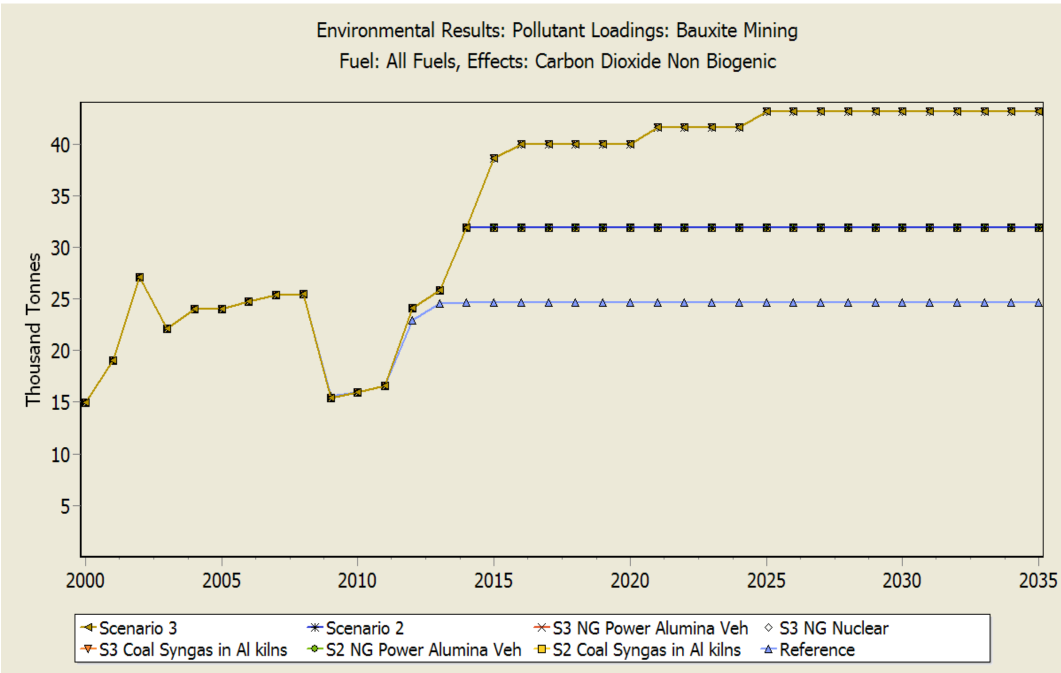


Figure 3.21: CO_2 Emissions from Bauxite Mining for Jamaica, All Scenarios (2009-35)



Transport

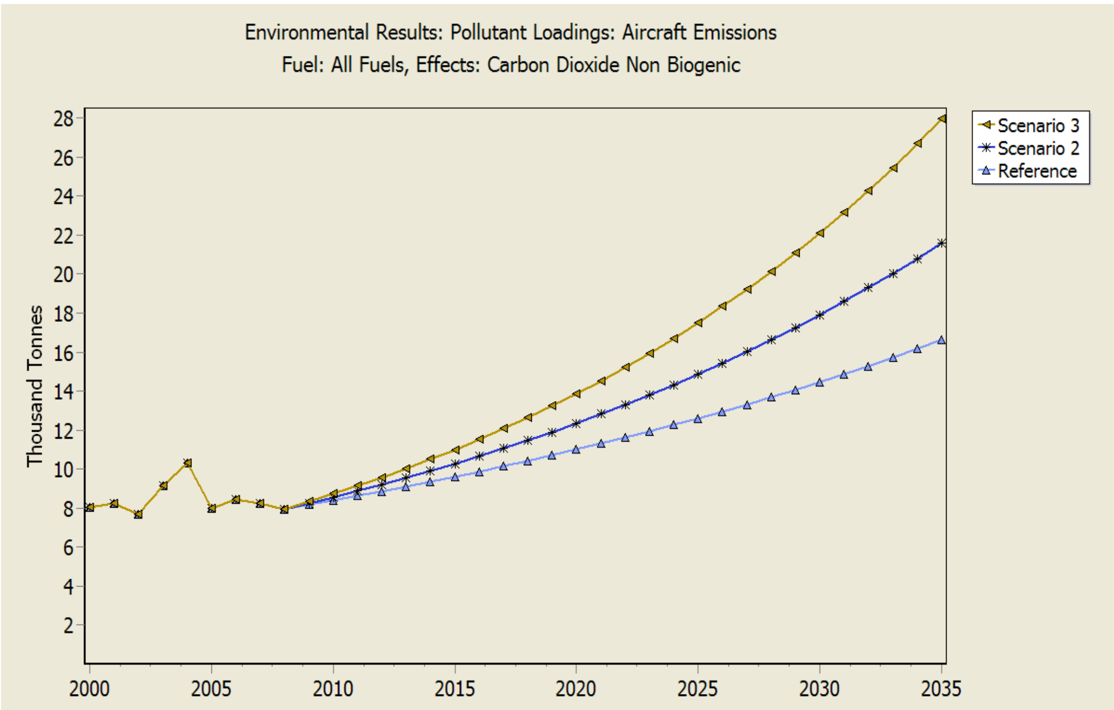
The transport sectors considered were:

- Rail;
- Aircraft; and
- On-road and off-road traffic.

Rail: Jamaica's rail traffic is limited to freight movement by the bauxite and alumina industry. Bauxite is shipped by rail to some alumina plants from transfer points near bauxite mines. Alumina is shipped from the alumina refineries to ports and fuel, caustic and other materials are shipped from the port to the refineries. Data for fuel use for rail activities has not been consistently compiled and hence the estimates for rail have been aggregated with diesel fuel use for the Bayer process.

Aircraft: Aircraft emissions in the 2000-05 national GHG inventory were based on detailed analysis of landing and take-off (LTO) emissions at the international and domestic aerodromes and cruising emissions during intra-island flights. The LTO emissions were based on modelling using the US Federal Aviation Administration (FAA) Emissions Dispersion Modelling System (EDMS) model and cruising emissions were based on emission factors available in EDMS and US EPA AP42[22]. Projections of aircraft emissions were based on projections of air traffic movements at the two international airports that are contained in Jamaica's Master Plans (to 2022) for the airports (Figure 3.22). As noted earlier, the Reference Scenario assumes a 5 percent growth in LTOs to 2035, with a 7 percent and 9 percent growth for S2 and S3 respectively.

Figure 3.22: Domestic Aircraft CO_2 Emissions for Jamaica, All Scenarios (2009-35)



On-Road and Off-Road Traffic: Fuel consumption (gasoline, diesel and lubricants) by the on-road fleet accounted for about 23 percent of Jamaica's energy consumption in 2008. It is therefore critical to obtain reliable estimates of projected fuel consumption and GHG emissions for the mitigation scenarios. The energy consumption and GHG emissions of on road vehicles are determined (inter alia) by the vehicle weight age (model year) and fuel type. Data for the entire fleet of licensed vehicles were obtained in order to determine the numbers of vehicles by weight class and age. In order to assign all vehicles to appropriate weight classes and fuel type the raw fleet data had to be edited to:

- eliminate duplicates (based on chassis numbers)
- add missing vehicle weights (to allow allocation into vehicle weight classes)
- correct incorrect units in weights (e.g., use of pounds instead of kg for some vehicles)
- correct fuel assignments
- assign some urban buses to the appropriate vehicle class
- reallocate some vehicles in the tractor and trailer categories

It should be noted that some of the vehicles designated as motor tractors and trailers include vehicles such as forklifts (some of which use LPG fuel), cranes and other off-road equipment. The editing was based on various information sources such as manufacturers' vehicle specifications and vehicle identification number (VIN) codes, information from Jamaica Urban Transit Company (JUTC) and Transport Authority (TA). The fleet data for 2000, 2005 and 2008 (after editing indicated above) are shown in Table 3.7. The editing is not considered perfect, but rather sufficient to provide more reliable data than originally received.

Table 3.7: Jamaica's Motor Vehicle Fleet in 2000, 2005 and 2008

Vehicle Type	2000	2005	2008#
MOTOR CAR	270,005	355,091	408,269
MOTOR CYCLE	20,272	26,009	33,155
MOTOR TRACTOR	443	818	1,728
MOTOR TRUCK	91,498	120,883	139,481
TRAILER	2,757	3,815	4050
Total	**384,975**	**506,616**	**586,683**

Note – Excludes duplicate records

Estimates of fuel consumption (mileage) and emissions (emission factors) were determined using a US EPA emissions model MOBILE6 for various combinations of vehicle classes and fuels (e.g., g/vehicle–km for each vehicle class). The estimates, together with the number of vehicles and the annual vehicle kilometres travelled (VKMT) in each weight class by fuel, allowed calculation of total fuel use.

Estimates for annual VKMT were based on limited surveys conducted by STATIN/PIOJ[23] and the Ministry of Transport & Works (MTW)[24]. The former was based on a survey of householders in connection with residential energy end use, while the latter was based on odometer readings taken at four parish Island Traffic Authority (ITA) vehicle inspection depots for vehicles (of all types) that were inspected during limited periods. In the latter survey, just over 1000 of the ~2400 odometer data pairs were rejected because of uncertain/incorrectly entered dates or odometer readings.

The average VKMT from the two surveys are summarised in Table 3.8. Although the MTW survey data were broken down by fuel type, data for the diesel motor cars and motor cycles are excluded because the sample sizes were too small. VKMT for diesel motor cars were assumed to be the same as for gasoline fuelled cars and for motor cycles were assumed to be the same as used previously.

Table 3.8: Summary of VKMT Estimates from Surveys

Survey	Fuel	Vehicle Type	VKMT (km/y)
MTW	Diesel	Motor Car	
		Motor Cycle	0
		Motor Truck	31,477
MTW	Petrol	Motor Car	29,961
7		Motor Cycle	33,786
		Motor Truck	21,193
PIOJ/STATIN	Not Specified	Motor Car	7,956
		Pick up	6,604
		SUV	5,876
		Minivan/Bus	12,740
		Motor Cycle	7,748

The Pickup, SUV and Minivan/minibus vehicle types in the PIOJ/STATIN survey were aggregated as Motor Trucks in the MTW survey. The VKMT estimates in the PIOJ/STATIN survey are considerably lower than that in the MTW survey. It is likely that the MTW survey included a high proportion of vehicles operated as hackney, public or private which are expected to have higher VKMT. Both surveys are subject to considerable uncertainty.

In applying the MOBILE6 model, local data included the age distribution of vehicles in each class, fuel properties, ambient conditions, average road and highway speeds, the diesel vehicle sales by vehicle class, and the mileage accumulation by vehicle class, the roadway distribution (freeway, arterial/collector, local roads and ramps).

The age distribution of the fleet (based on the “traditional” vehicle classes) is shown in Figure 3.23. Note that in Figure 3.23, vehicles with model years of 1985 or earlier are grouped together.

Figure 3.24 shows CO_2 the loadings from the on road fleet for selected scenarios. A breakdown of the CO_2 loadings into the eight vehicle classes for the Reference Scenario is illustrated in Figure 3.25. The vehicle classes in Figure 3.25 are as follows:

LDGV	Light duty gasoline vehicles	LDDV	Light Duty diesel vehicles LDDT
LDGT12	Light duty gasoline trucks	LDDT	Light duty diesel trucks
LDGT34	Light duty gasoline trucks	HDDV	Heavy duty diesel vehicles
HDGV	Heavy duty gasoline vehicles	MC	Motor cycles

Figure3.23: Age Distribution of the Jamaican Vehicle Fleet (2008)

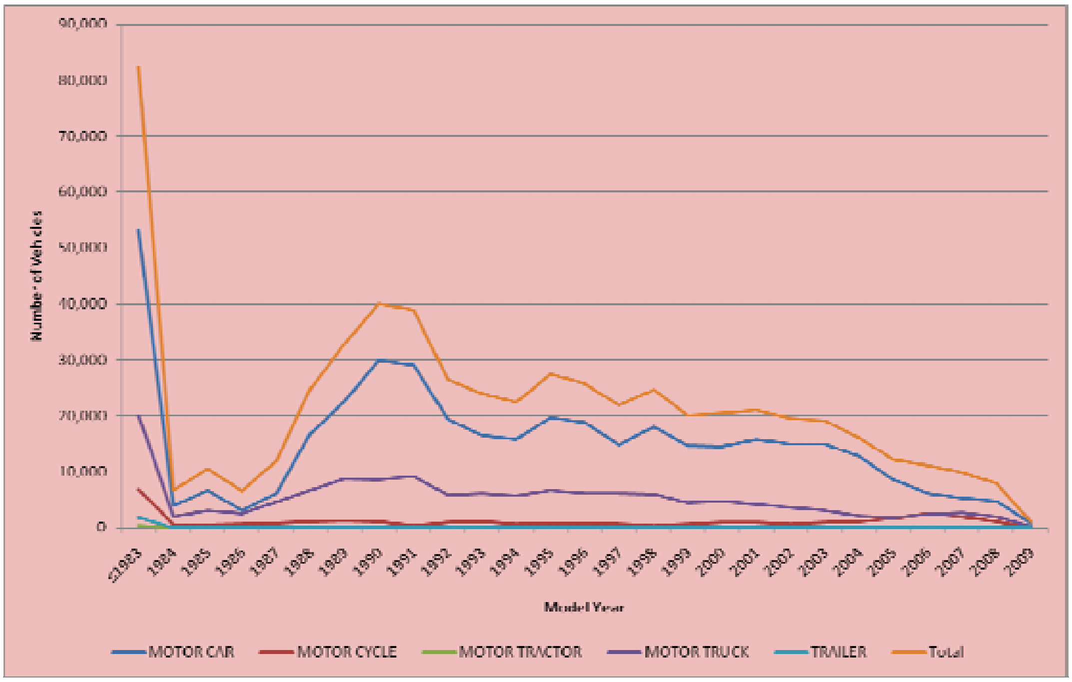


Figure 3.24: Final Environmental Loadings for On Road Fleet, Selected Scenarios (2009-35)

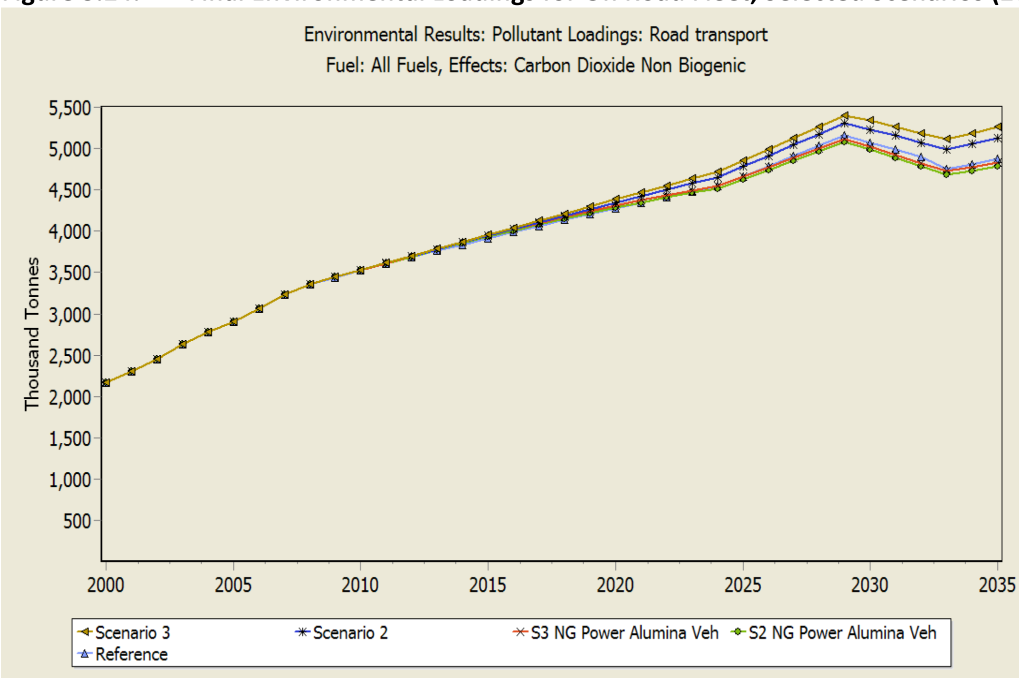
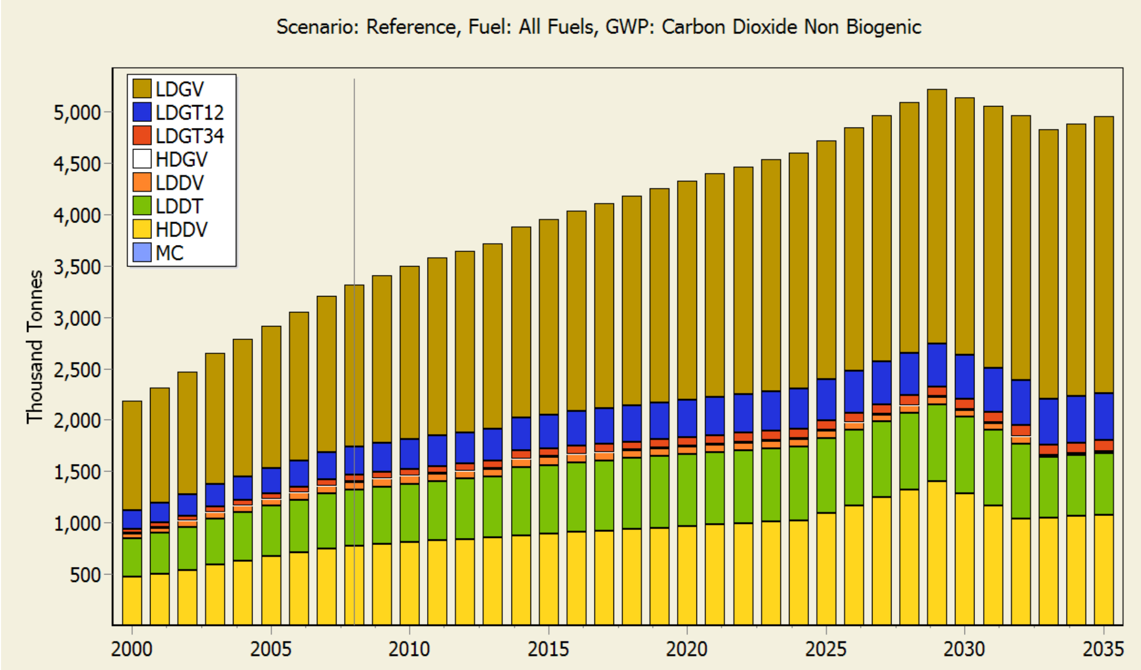


Figure 3.25: Final Environmental Loadings for On Road Fleet, Reference Scenario (2009-35)



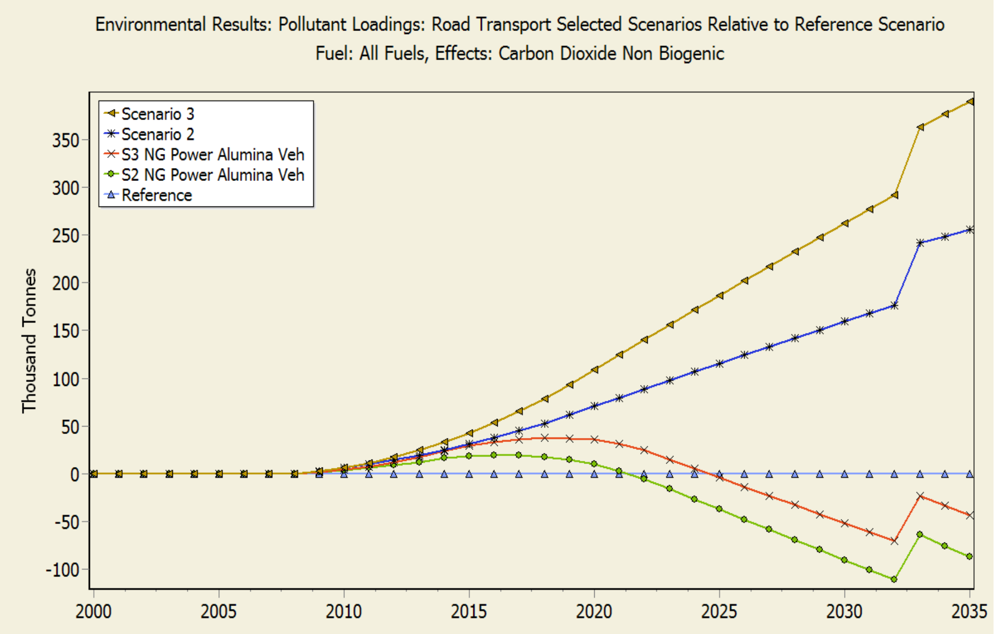
Mitigation measures for the on road fleet are centred on the use of natural gas in some of the fleet but no specific penetration targets were available. It should be noted that the Reference Scenario includes the introduction of E10 (as of 2010[24]), low sulphur diesel and gasoline as well as additional highway construction – both of which would impact emissions. The mitigation measures for *S2* and *S3* were therefore limited to assumed percentage of new vehicle registrations that are equipped to use CNG.

Consideration of CNG for motor cycles and heavy duty gasoline vehicles (HDGV) was excluded because it is either not feasible (in case of motor cycles) or because the number of vehicles (and hence the expected benefit) in the fleet is small.

The impacts of introducing CNG vehicles on CO_2 emissions are illustrated in Figure 3.26 relative to the Reference Scenario. The CO_2 emissions for scenarios with CNG vehicles (*S2 NG* and *S3 NG*) show reductions with net reductions (i.e., negative differences) after 2020/21 as sufficient vehicles enter the fleet.

[24] E10 was introduced in November 2009 and the first full year (2010) was modeled.

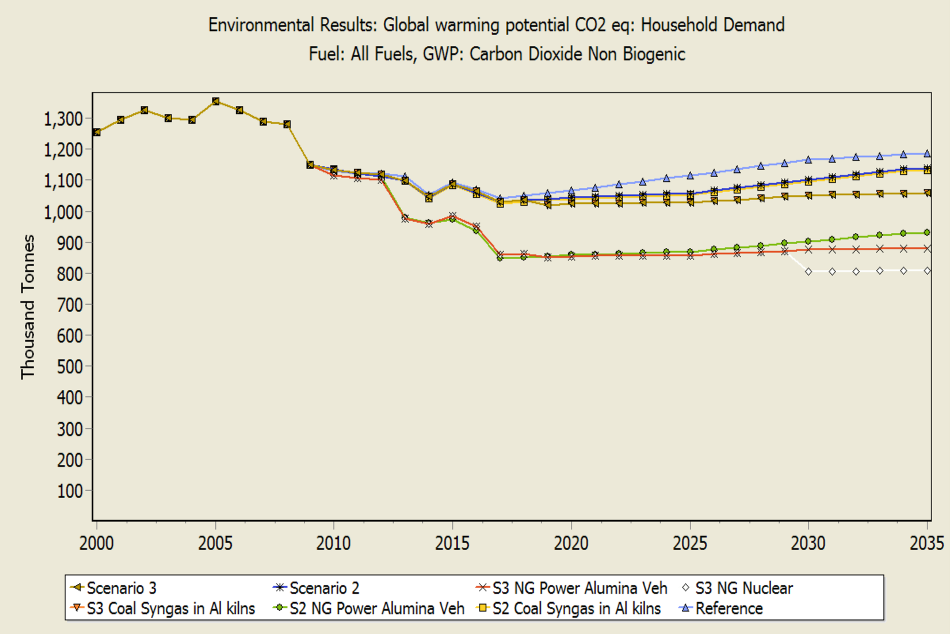
Figure 3.26: Final Environmental Loadings for Road Transport, Selected Scenarios Relative to the Reference Scenario (2009-35)



Household Demand

CO_2 emissions from residential demand are driven by population increases as well as by larger percentages of household acquiring appliances such as air conditioners, washing machines etc. This is illustrated in Figure 3.27, where energy increases outweigh the mitigation measures such as the additional substitution of incandescent bulbs by CFL bulbs and more efficient appliances.

Figure 3.27: Final Environmental Loadings for Non Biogenic CO_2 for Residential Demand, All Scenarios (2009-35)



The contributions to CO_2 emissions allocated to the various demand sectors in the household category is illustrated in Figure 3.28 for the Reference Scenario. The highest percentage of the household CO_2 emissions is from “all other” followed by refrigeration, lighting and cooking (all types - LPG, Electric stoves, charcoal and firewood). There are no mitigation measures proposed for cooking but measures for lighting (additional CFL bulbs), televisions and refrigeration (adoption of Energy Star standards) will reduce annual household emissions. The impacts of these measures are illustrated in Figures 3.29 to 3.31.

Figure 3.28: Final Environmental Loadings for Non Biogenic CO_2 from Residential Demand, Reference Scenario (2009-35)

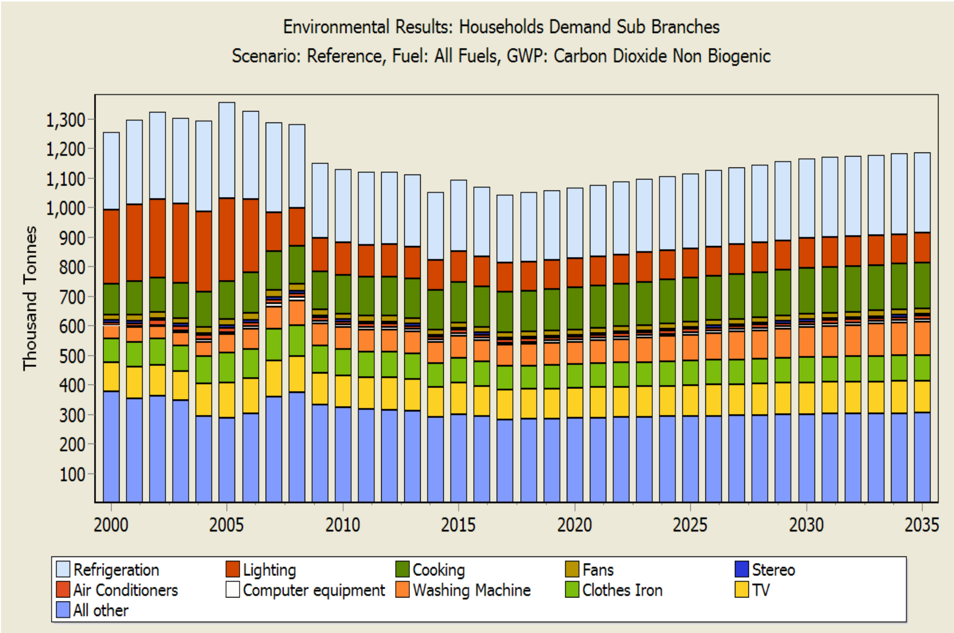


Figure 3.29: Lighting Mitigation Measures in Household Demand Category

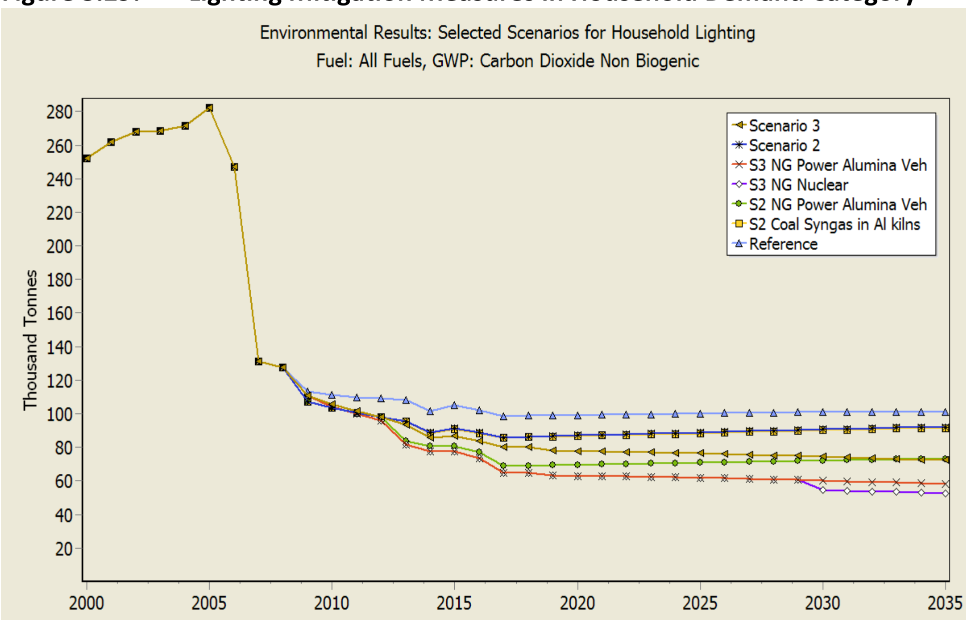


Figure 3.30: Television Mitigation Measures in Household Demand Category

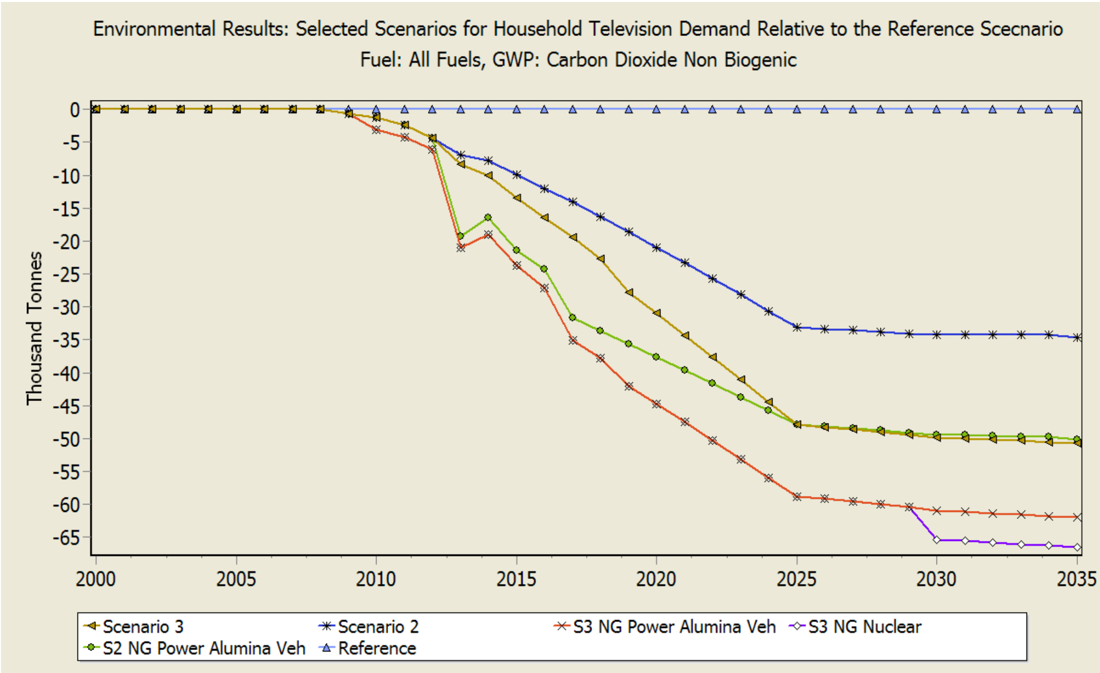
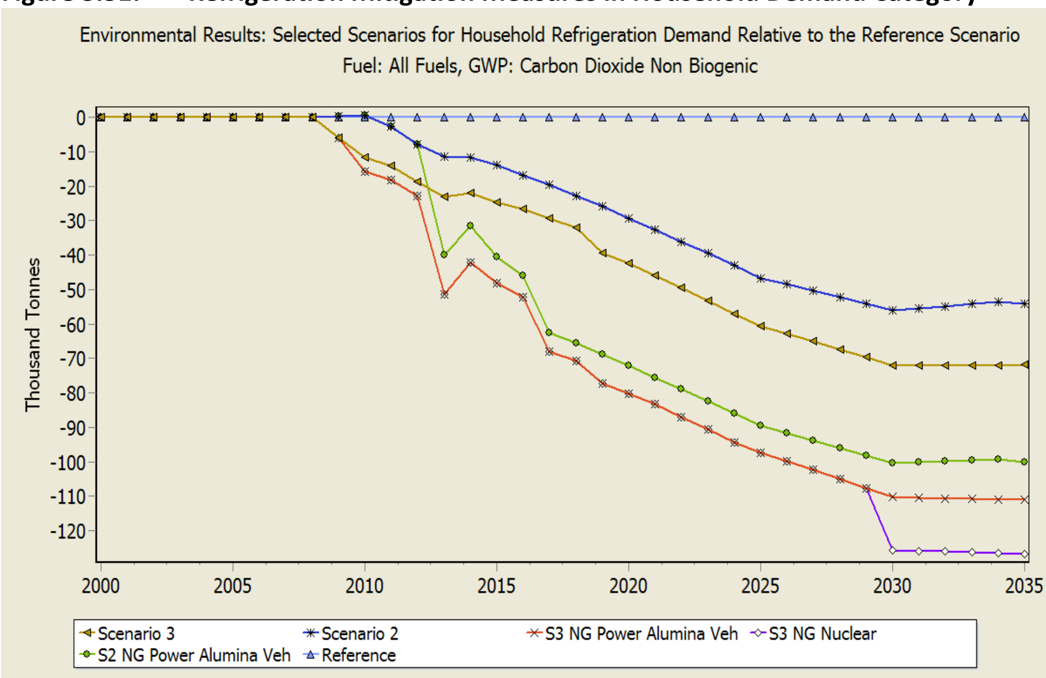


Figure 3.31: Refrigeration Mitigation Measures in Household Demand Category



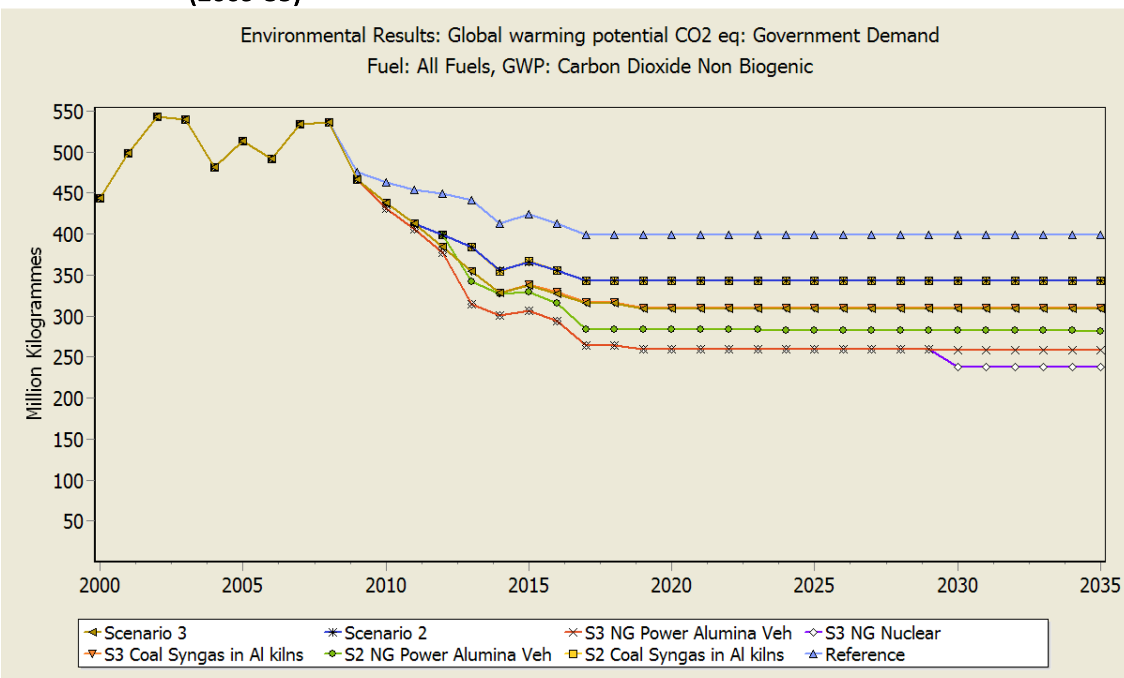
Government Demand

The government category comprises hospitals, NWC, and “Other Government”, since electricity and fuel use data are available for these groups. An extensive and detailed audit of hospitals provided detailed energy consumption and “activity” (types of energy consuming devices) data for 2006. The purpose of the audit was to develop energy conservation strategies. These consisted of a number of “investment packages” for which energy savings and implementation costs were developed. These packages were used in LEAP to determine the implications for environmental loadings (GHG emissions) and energy demand savings.

Figure 3.32 shows the overall changes in the Government category for CO_2 emissions for all scenarios. These figures show the reductions in CO_2 emissions that would be achieved. In the absence of details for the energy conservation measures that NWC would undertake, it was assumed that there would be reductions of 5 percent in each of three years starting in 2009 for S2 and 10 percent in each of two years starting in 2012 for S3.

For the “Other Government” category, the public sector energy conservation program was assumed to meet its target of a 15 percent reduction in energy use over five years.

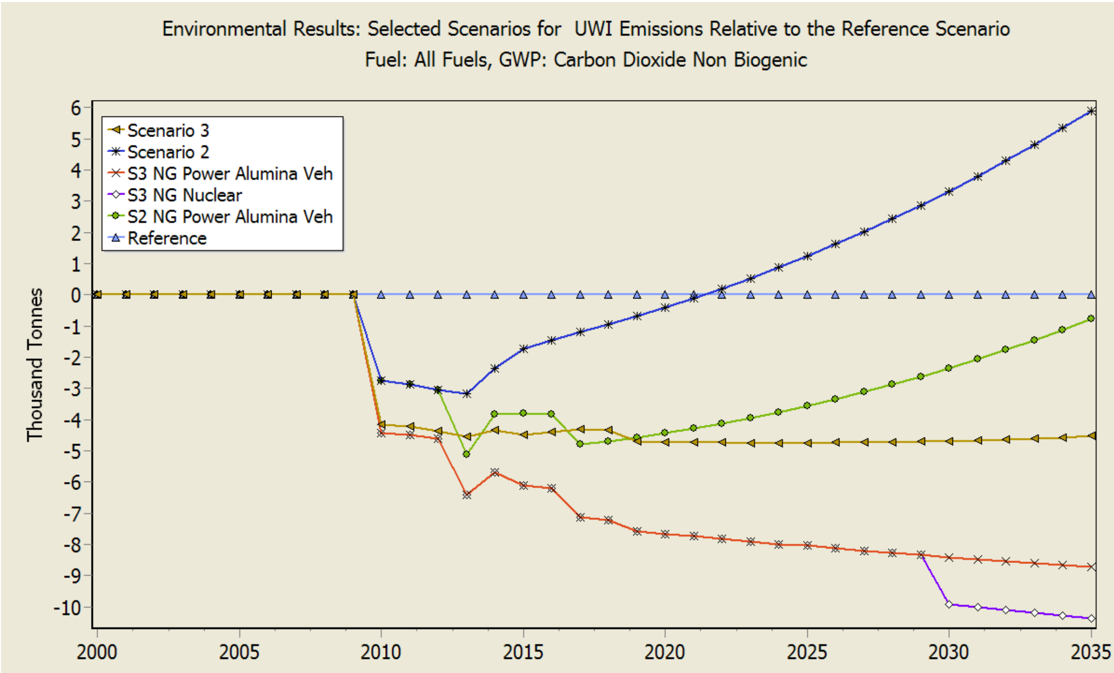
Figure 3.32: Mitigation Measures in the Government Demand Category, Selected Scenarios (2009-35)



Other Demand: Rates 20, 40A, 50 and 60

These customers use only electricity and there were no specific mitigation measures other than general energy conservation. Although significant energy conservation measures have been undertaken at UWI[25] (a Rate 50 customer), the vast majority of the measures (refrigerant substitution, lighting changes, energy management) were undertaken between 2006 and 2008. The impacts on CO_2 emissions of projected growth and additional energy conservation measures are illustrated in Figure 3.33.

Figure 3.33: Mitigation Measures from UWI Initiatives for Selected Scenarios Relative to Reference Scenario (2009-35)



Transformation

The transformation categories consist of transmission (of electricity) and transformation (petroleum refining and electricity generation and charcoal production) activities.

Although the emissions directly associated with these activities are allocated to demand categories, it is instructive to indicate the emissions directly associated with these activities. The LEAP model produces electricity outputs to match the demand based on (among other things) on the load shape, the availability of generating units and the order of dispatch etc.

<u>Environmental Loading of Transformation Processes</u>

Figure 3.34 shows the CO_2 emissions associated with transformation activities namely petroleum refining, electricity generation, coal gasification and charcoal making for the various scenarios.

Figure 3.34: CO_2 Emissions from Transformation Processes in Jamaica, All Scenarios (2009-35)

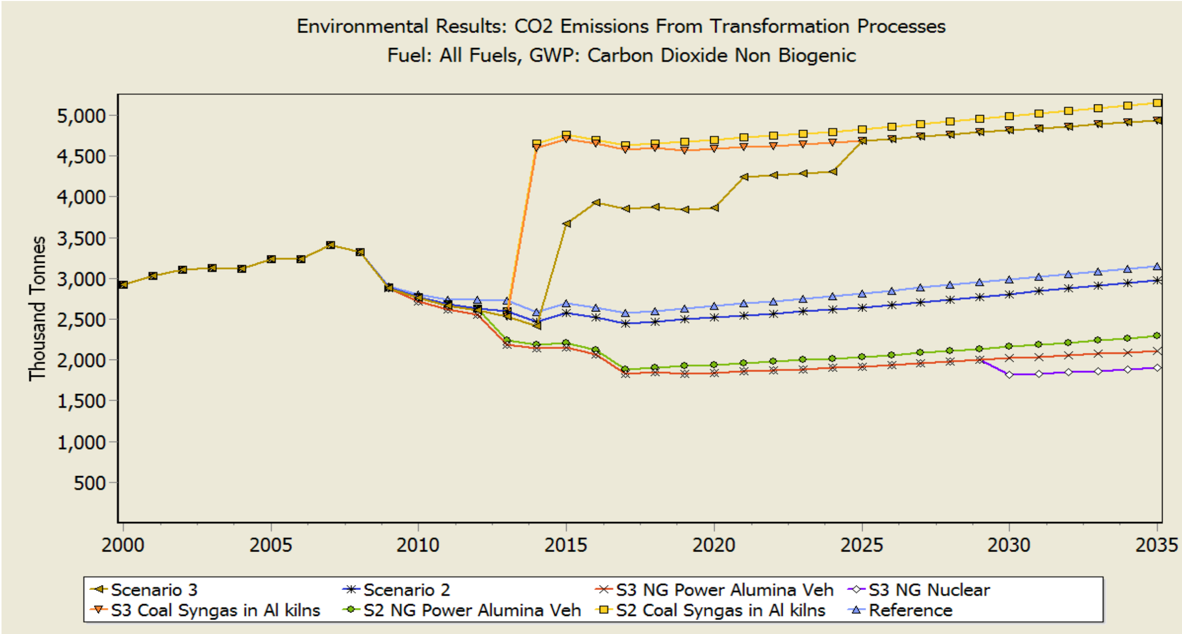
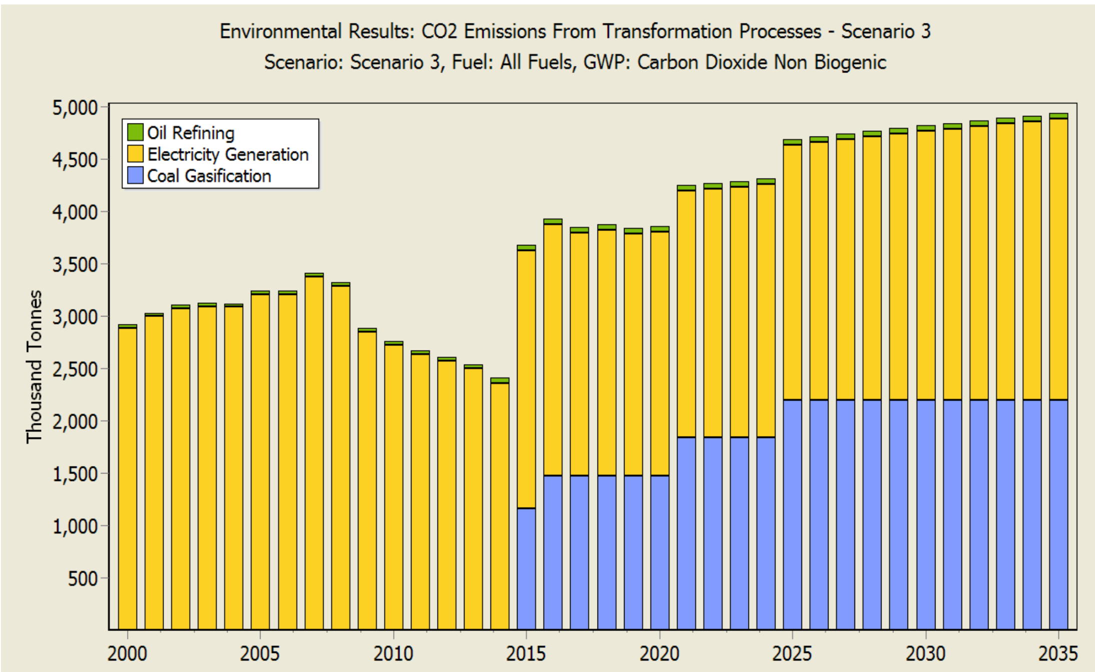


Figure 3.35 illustrates the contributions from the transformation processes for S3 (which includes significant energy from coal gasification for use in alumina kilns).

Figure 3.35: CO_2 Emissions from Transformation Processes under Scenario 3 (2009-35)



Other Selected Transformation and Energy Demand Results

Electricity Generation: The electricity generation outputs for the three scenarios are shown in Figure 3.36. A comparison of the actual and modelled generation output for 2000-08 (Figure 3.37) shows a good match. The household uses required the most attention and further refinement of the allocations are in order.

Figure 3.36: Electricity Generation Outputs, Selected Scenarios (2009-35)

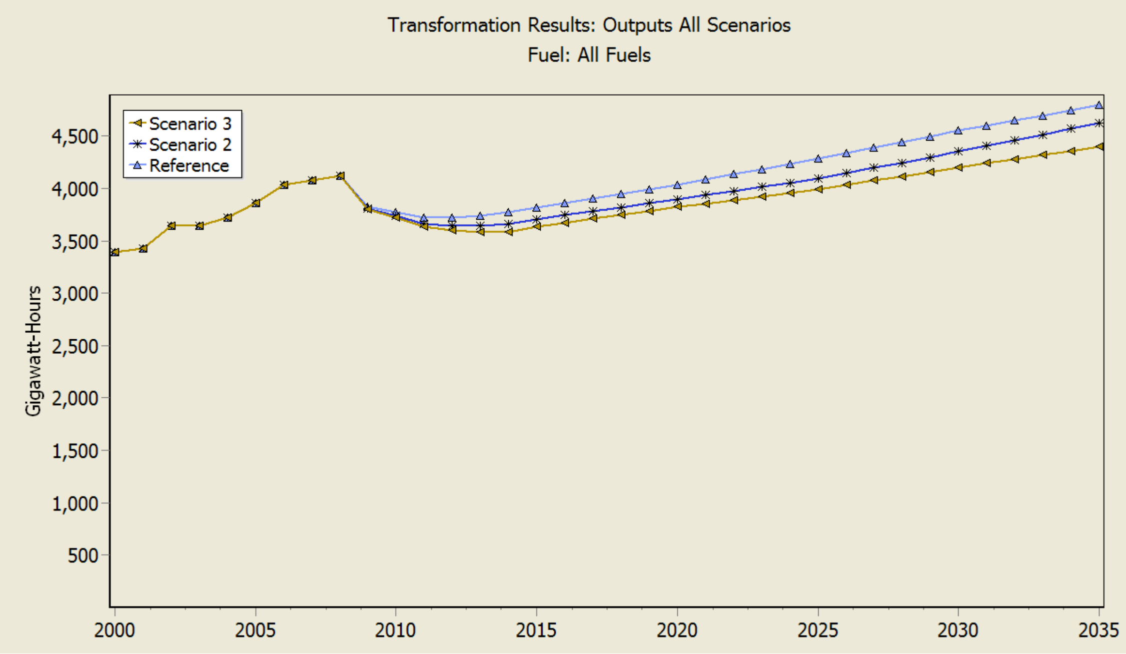
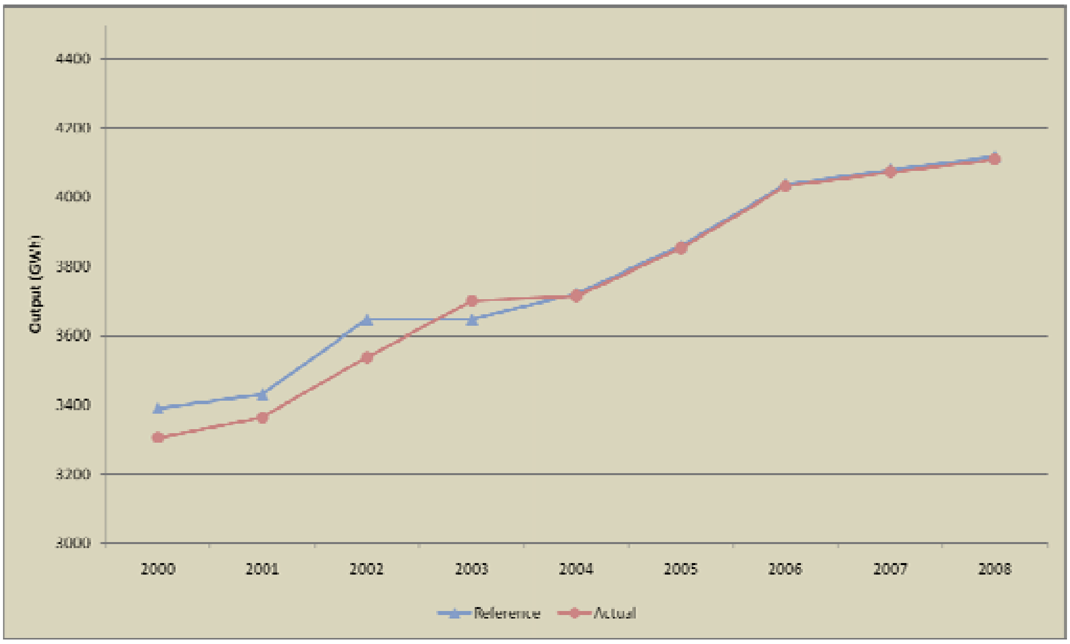


Figure3.37: Comparison between Actual and Modelled Electricity Generation Outputs (2000-08)



The total electricity generating capacity various additions to capacity and unit closures (retired or mothballed) that were assigned to the various scenarios are illustrated in Figure 3.38 (total capacity), Figure 3.39 (additions) and Figure 3.40 (retirements).

Figure 3.38: Electricity Generation Capacity, Scenarios Reference, *S2*, *S3* and *S3 NG*NU (2009-35)

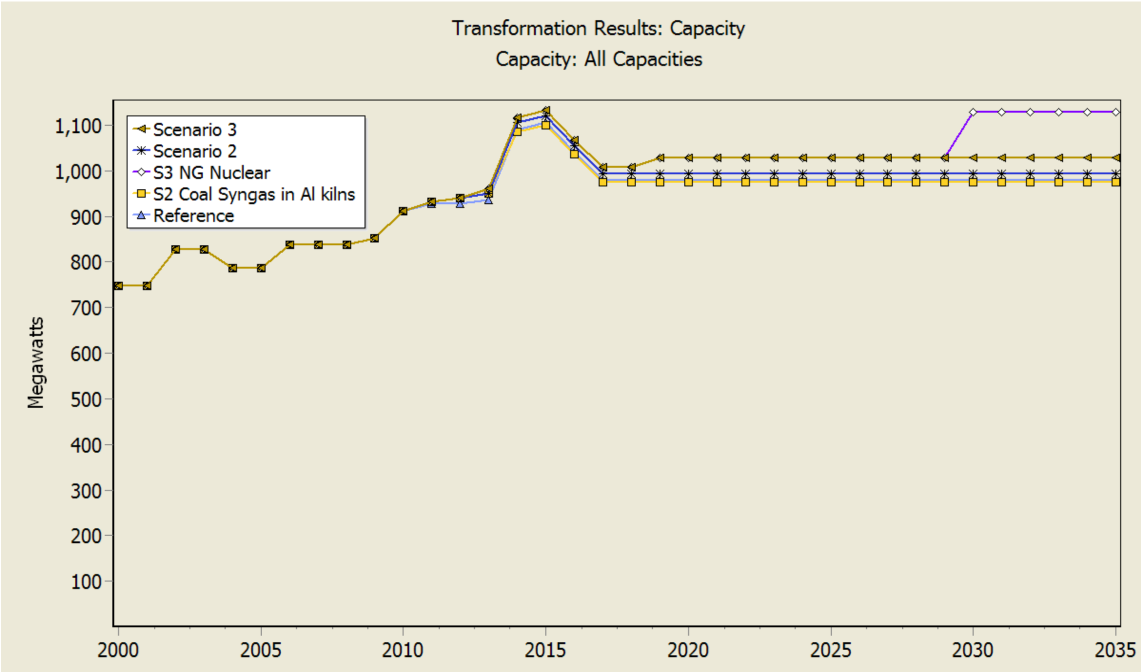


Figure 3.39: Transformation Results: Electricity Generation Capacity Added, Scenarios Reference, *S2*, *S3* and *S3 NG*NU (2009-35)

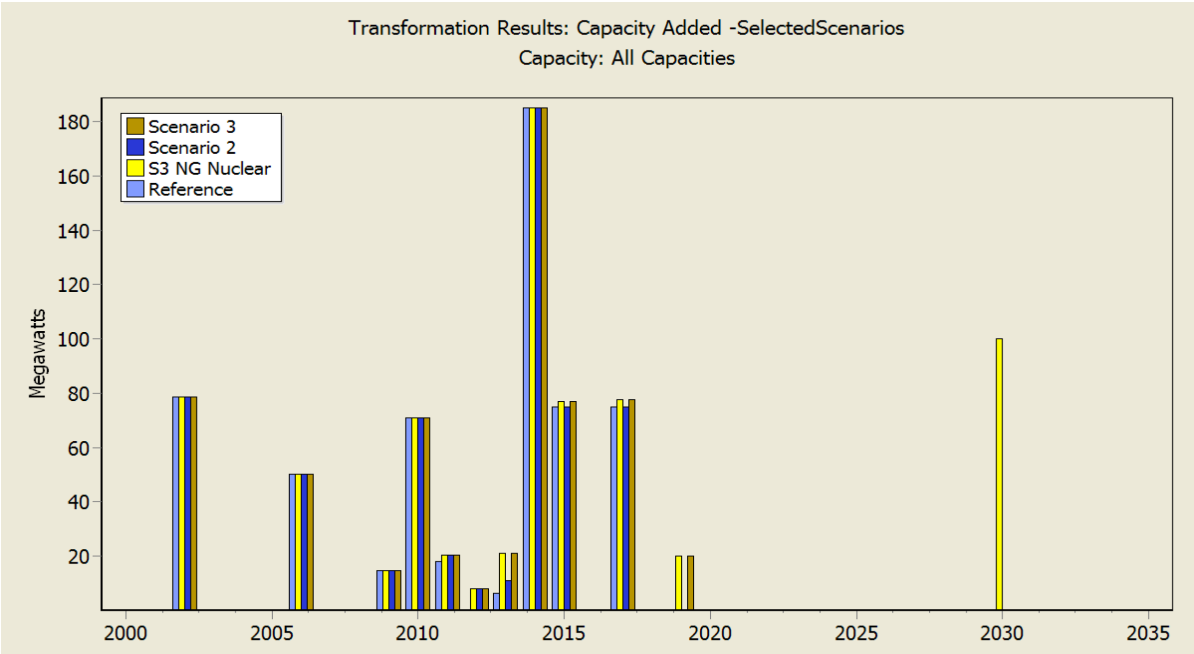
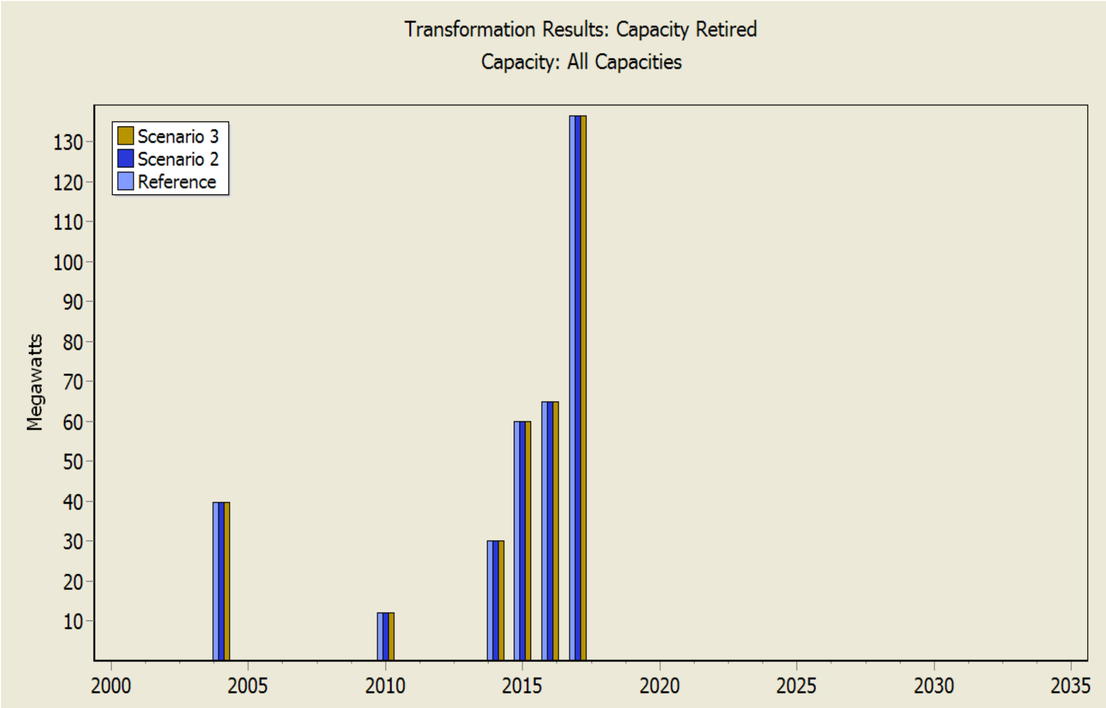
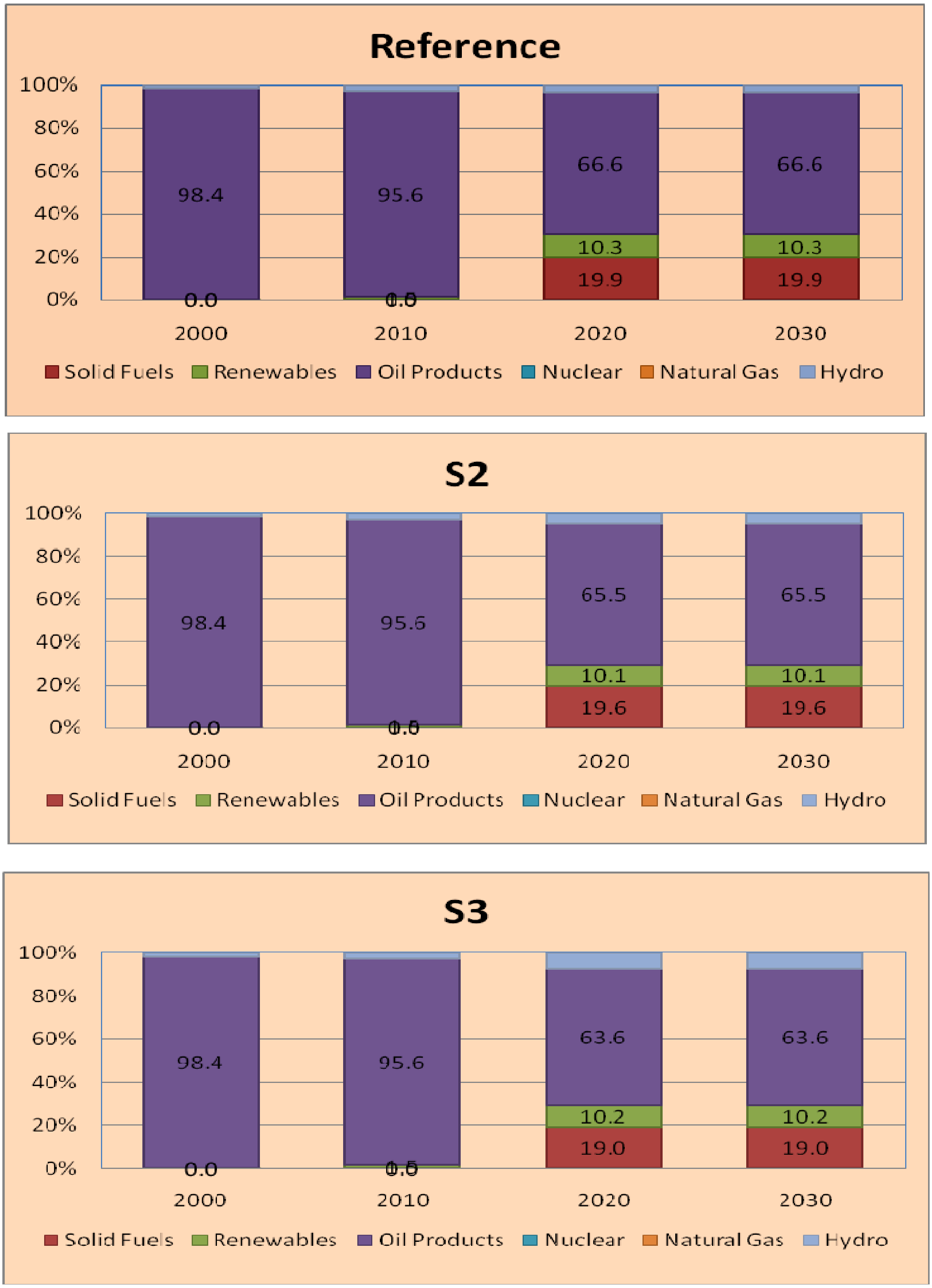


Figure 3.40: Transformation Results: Electricity Generation Capacity Retired/Mothballed, Scenarios Reference, *S2*, *S3* (2009-35)



Electricity Generation Mix: The changes in the mix of renewable (wind, hydro, municipal solid waste) and non-renewable fuels (coal, petcoke, oil) used for the electricity generation capacity for the three scenarios are shown in Figure 3.41. The percentage of renewables used for electricity generation in the Reference scenario in 2010 is 5 percent. In 2020, the percentages of renewables are 11.9 percent, 12.5 percent and 13.2 percent for the Reference, *S2* and *S3* scenarios respectively compared with the Energy Policy target of 15 percent by 2020 and 20 percent by 2030 but for all sources of energy.

Figure 3.41: Percentages of Fuel Types in the Reference, *S2* and *S3* Scenarios



Final Energy Demand

The mix of fuels in use in the various scenarios is illustrated in Figures 3.42 to 3.45 for scenarios *Ref, S2, S2NG, and S3 NG*. The changes in the mix of fuels are clear when either coal or natural gas is used.

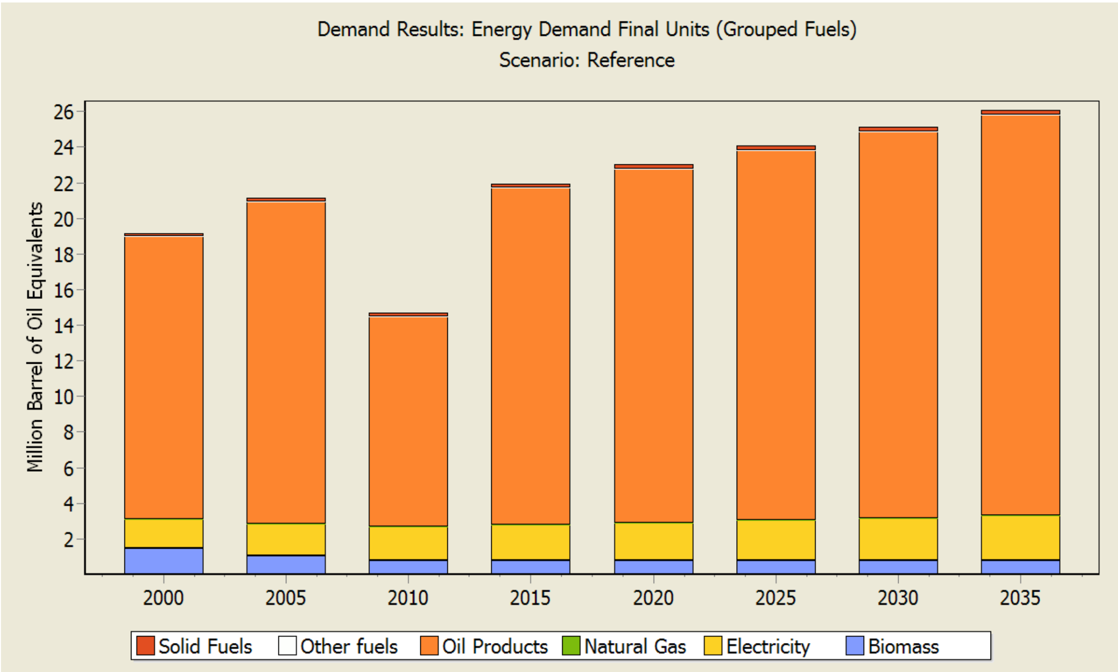


Figure 3.42: Final Energy Demand All Fuels (Grouped): Reference Scenario

Figure 3.43: Final Energy Demand All Fuels: Scenario *S2* (Coal)

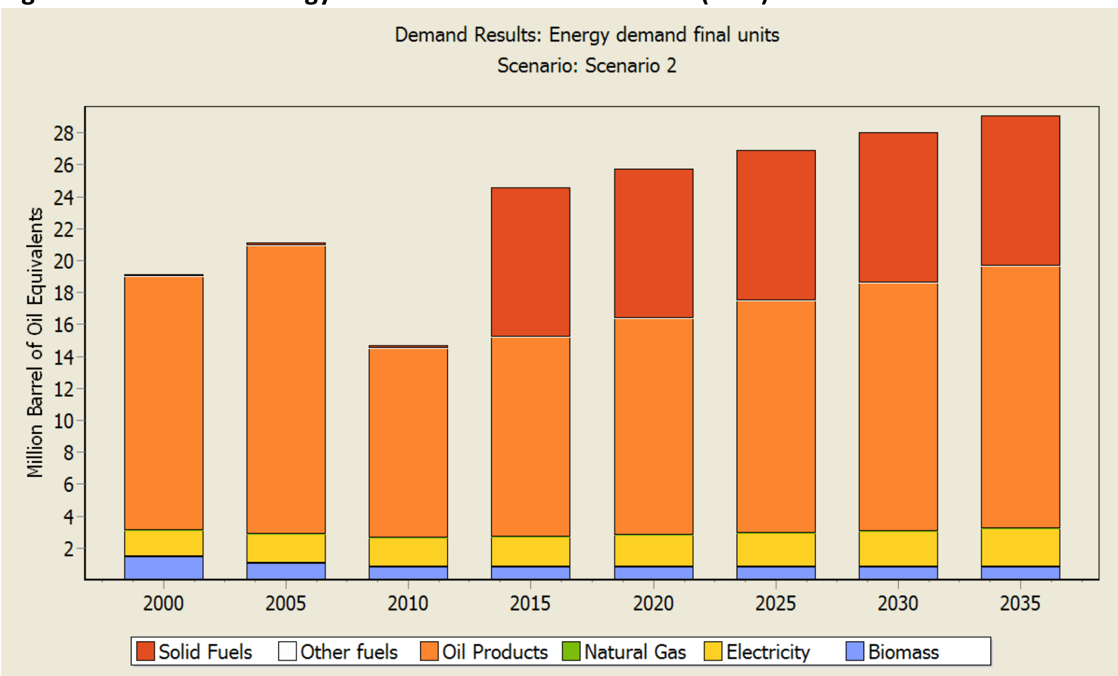


Figure 3.44: Final Energy Demand All Fuels: Scenario *S2 NG* (Natural Gas for Power, Alumina, and Vehicles)

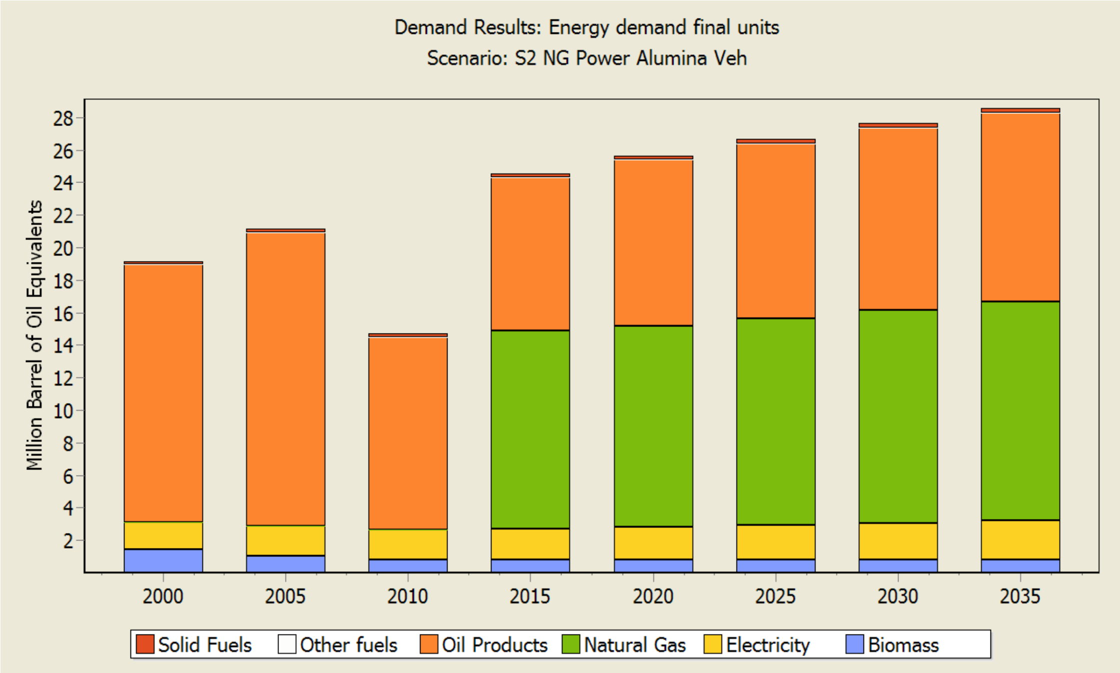
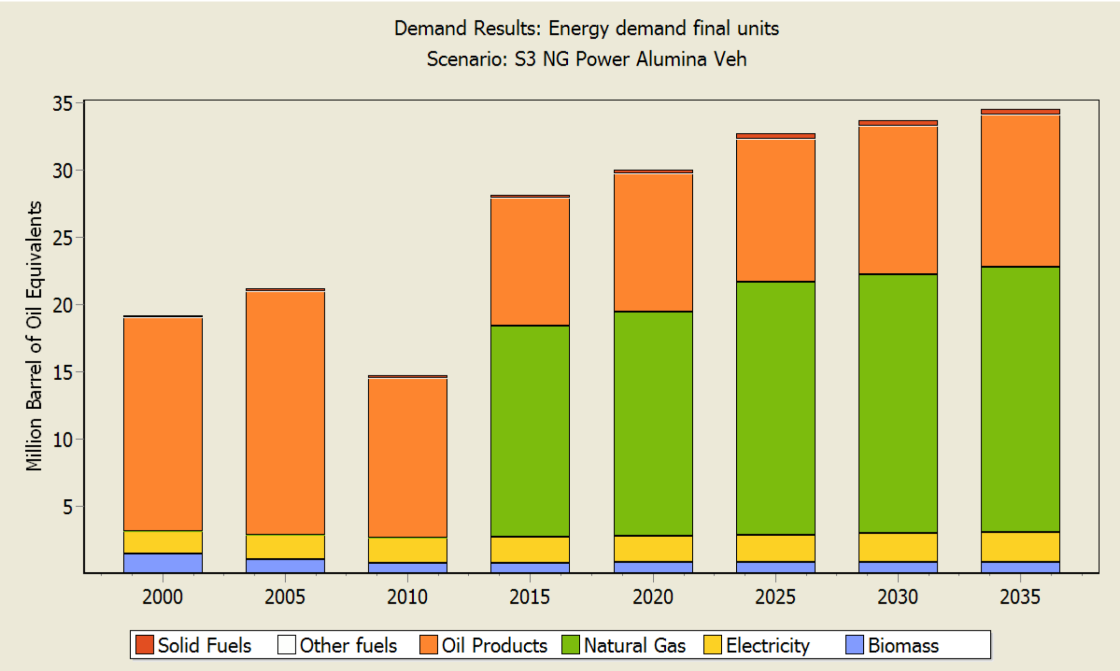


Figure 3.45: Final Energy Demand All Fuels: Scenario *S3 NG* (Natural Gas for Power, Alumina, and Vehicles)



Refinery Outputs

The refinery outputs (any including imports) to meet the demand are shown in Figures 3.46 to 3.50 for the *Reference*, *S2, S2 NG, S3* and *S3 NG* respectively. These scenarios all show changes in the fuel requirements (especially for diesel and HFO) relative to the Reference scenario.

Figure 3.46: Transformation Outputs: Refinery Fuels Outputs (thousand boe): Reference Scenario for Selected Years

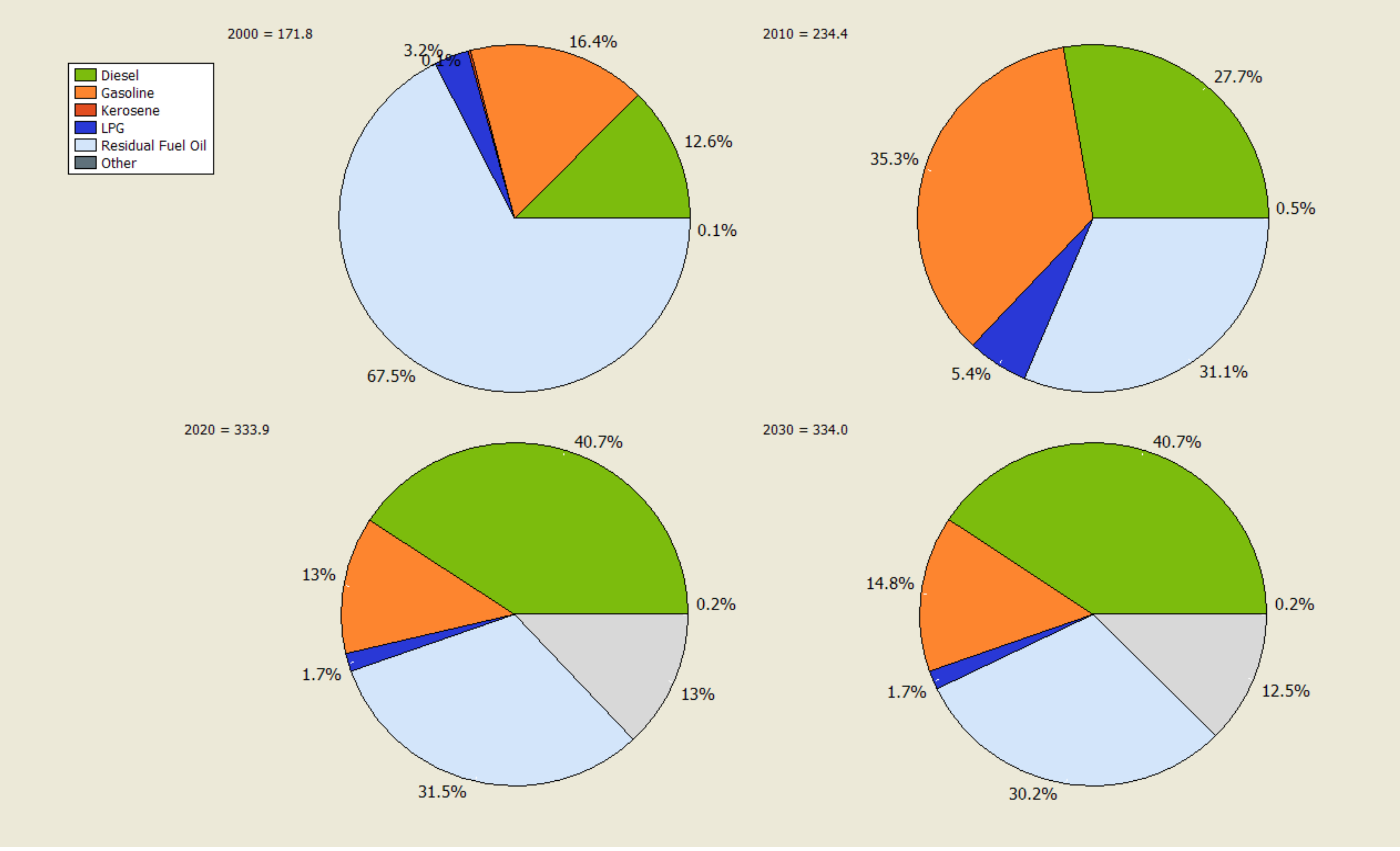


Figure 3.47: Transformation Outputs: Refinery Fuels Outputs (thousand boe): Scenario *S2* for Selected Years

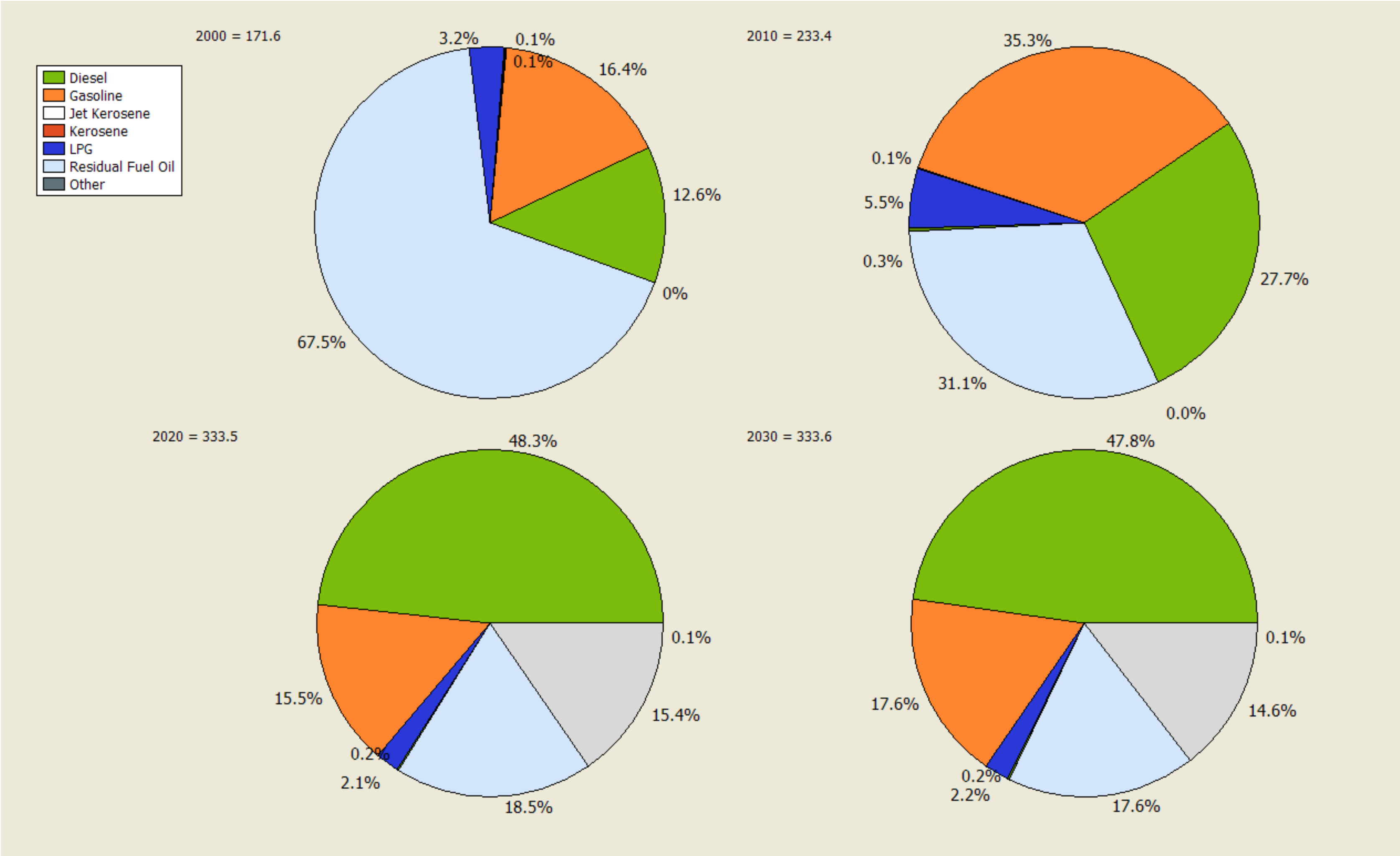


Figure 3.48: Transformation Outputs: Refinery Fuels Outputs (thousand boe): Scenario *S2 NG* for Selected Years

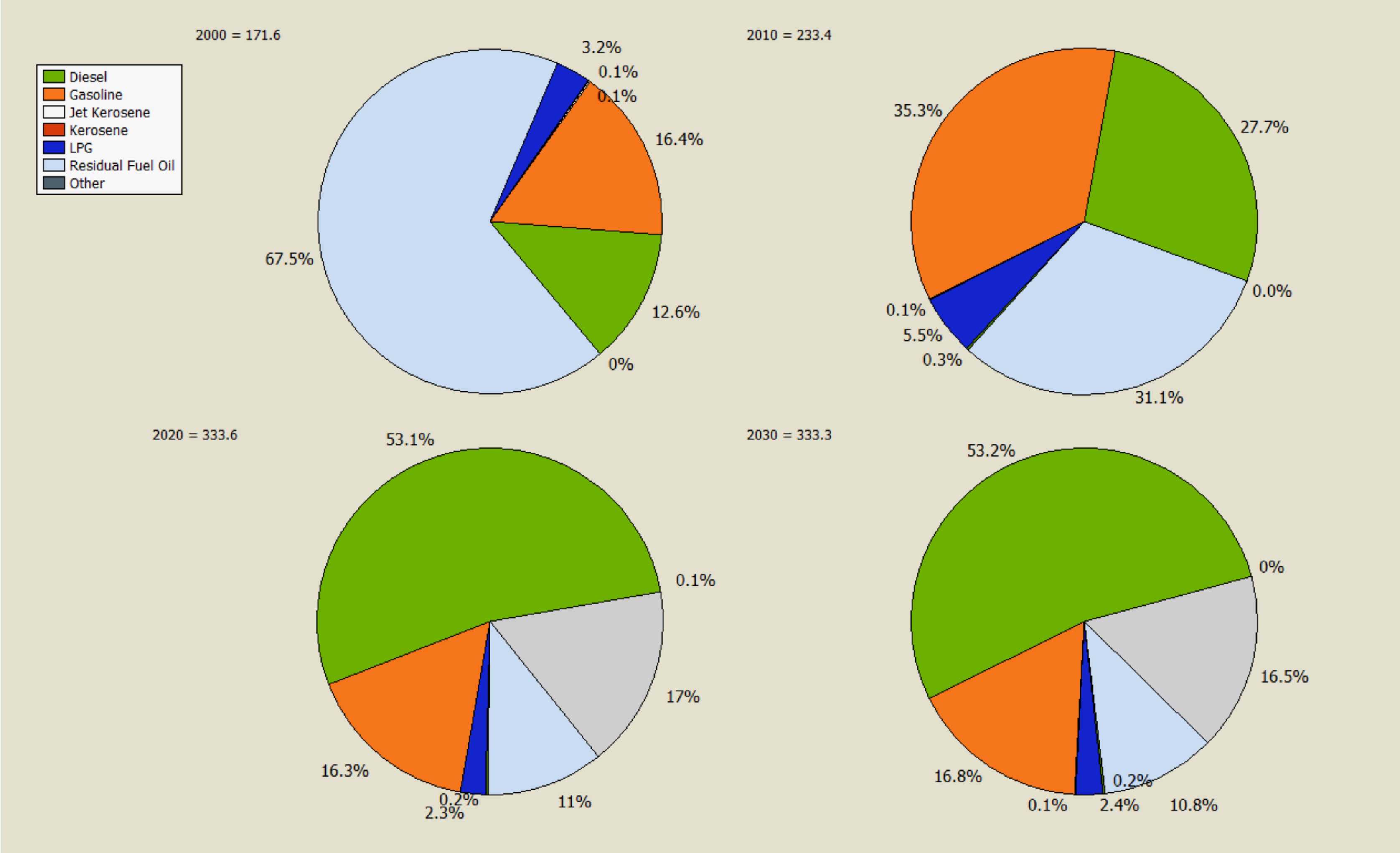


Figure 3.49: Transformation Outputs: Refinery Fuels Outputs (thousand boe): Scenario *S3* for Selected Years

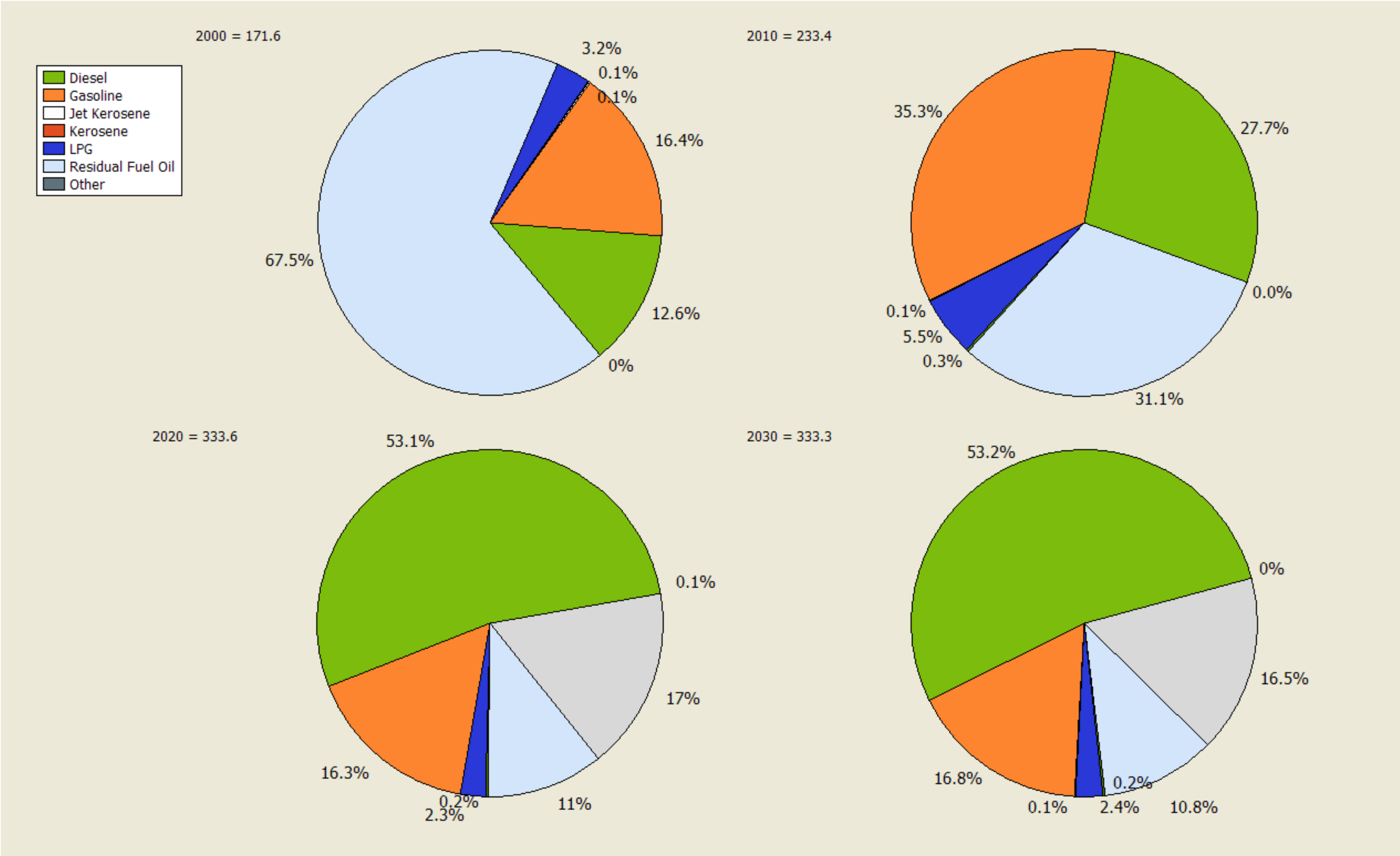
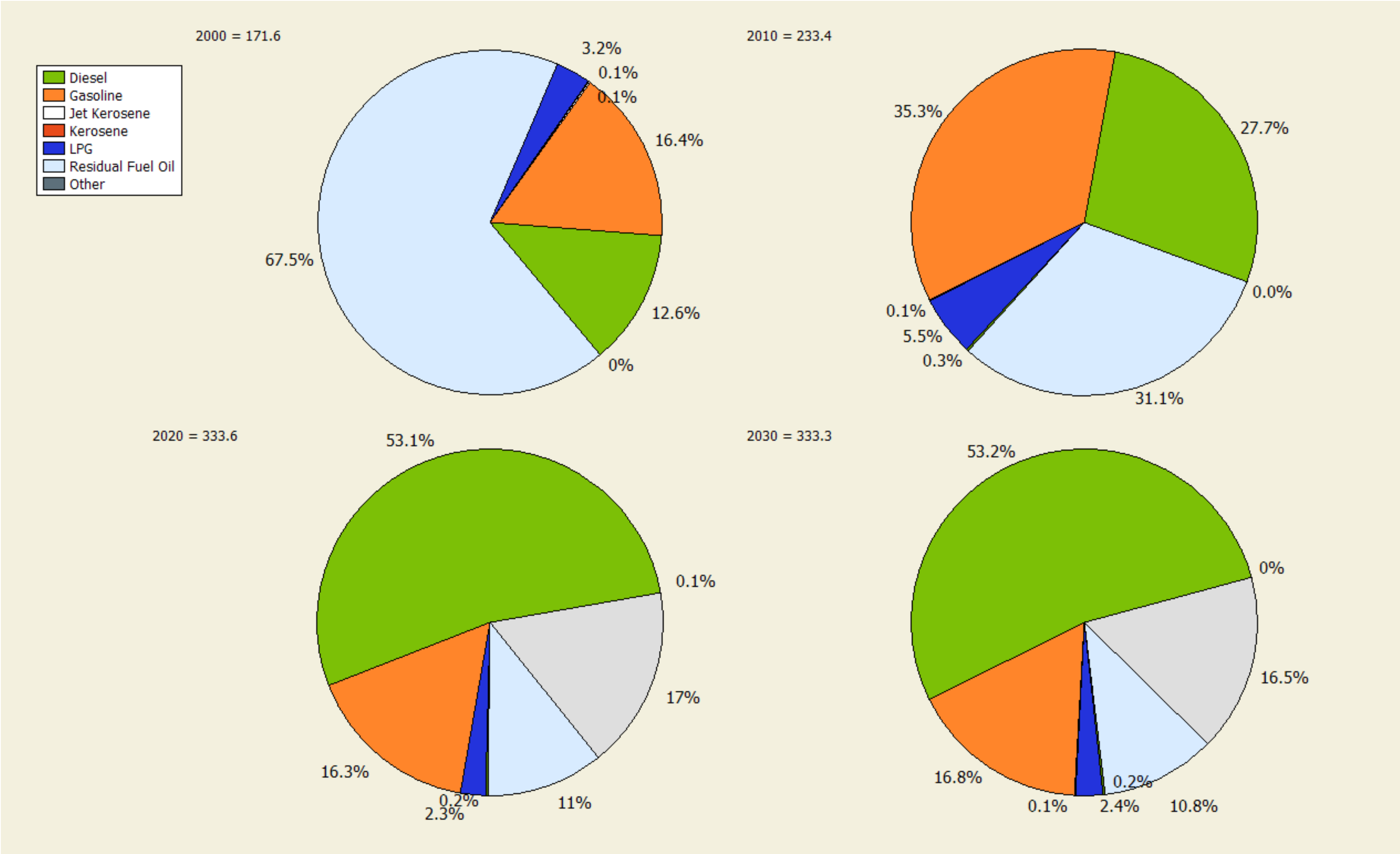


Figure 3.50: Transformation Outputs: Refinery Fuels Outputs (thousand boe): Scenario *S3 NG* for Selected Years



Summary of How Mitigation Measures Affect Carbon Dioxide Emissions, 2000-35

For all scenarios, the percentage change in the non-biogenic CO_2 emissions in 2035 relative to the year 2000 for the overall demand, transformation and non energy sector categories provide a measure of the impacts of factors (activity and energy intensity related) that affect emissions.

These percentage changes for each scenario are summarized in Figure 3.51. Also included in the figure are the percentage changes for sectors in these categories. Note that in the case of electricity use and other secondary fuel use in the demand category, the emissions occurring in the various transformation categories are allocated back to the relevant demand source.

Overall Demand: The left-most grouping in Figure 3.51 shows the percentage changes in CO_2 emissions for 2035 relative to 2000 for the overall demand in all scenarios. The overall CO_2 emissions in the energy demands for the reference, *S2* and *S3* scenarios increase by 29 percent, 52 percent and 98 percent respectively. This is consistent with the general increase in CO_2 generating (and energy consuming) activities because of population increases, fleet increases and increased bauxite and alumina production. These scenarios all entail additional coal fired electricity generation whose emissions easily outweigh the emission reductions from the much smaller additions of wind and hydro generating stations. In addition, *S3* also includes a major expansion in alumina refining capacity.

The major mitigation measure is the introduction of natural gas (scenarios *S2*NG, *S3*NG and *S3 NGNU*) and a nuclear plant in conjunction with natural gas in scenario *S3*NGNU. Because of these measures, the CO_2 emissions in these scenarios are lower than those in the corresponding *S2* and *S3* scenarios.

Cement Kiln Demands: Changes in CO_2 emissions due to cement kilns are driven primarily by increased clinker production. The completion of the new kiln in 2008 resulted in a major improvement in energy efficiency and those changes are therefore present in all scenarios. Note that since the electrical energy use in the cement mills is small (1.8 percent to 3.5 percent) relative to the energy used in clinker production, a grouping for cement mills is not included in Figure 3.51.

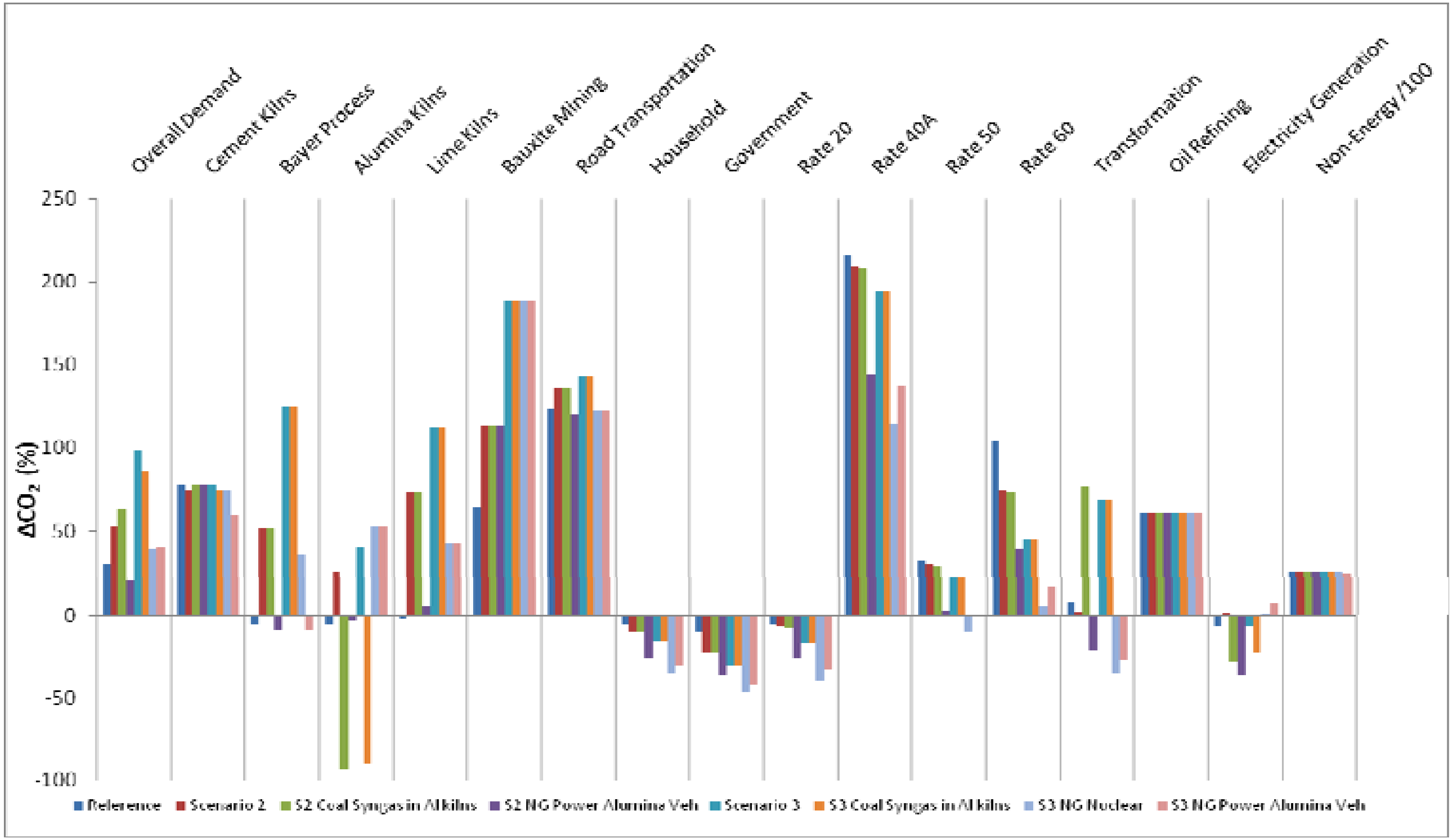
Bayer Process, Alumina Kiln and Lime Kiln Demands: The emissions from the Bayer process and alumina and lime calcination that entail using coal (*S2*, *S2* coal + Syngas, *S3* an d*S3* coal syngas) all result in increased emissions relative to the reference scenario. The *S3* scenarios have higher emissions than the corresponding *S2* ones because of increased alumina production.

The mitigation measure due to the use of natural gas in scenarios *S2* NG and *S3* NG and *S3* NGNU all dramatically reduce the CO_2 emissions relative to the corresponding scenarios in which coal is used.

Similar patterns occur in the case of lime and alumina kilns but the reduction is more dramatic in alumina kilns since alumina kilns cannot use coal directly (syngas is used).

In the case of bauxite mining, no change in fuel is contemplated in any scenario and hence emissions increase with production. It should be noted that the vertical axis in Figure 3.51 is a percentage change and does not reflect absolute emissions.

Figure 3.51: Summary of Percentage Changes in CO_2 Emissions in 2035 Relative to 2000 for Overall Demand and Transformation for Mitigation Assessment Scenarios



Household Demand: The CO_2 emissions for the household and government demand show reduced emissions in 2035 relative to 2000 for all scenarios. Although there is population increase (and hence an increase in the number of households or JPS customers) the increased demand because of this is more than offset by more energy efficient appliances, mitigation (energy conservation) measures and lower CO_2 emitting electricity generation when natural gas is used. [Remember that the CO_2 emissions for electricity demand are estimated by allocating the emissions to transformation activities.]

Government Demand: The mitigation measures in the hospitals and NWC as well as a government program to reduce electricity consumption by 15 percent lead to the overall reduction in CO_2 emissions for all scenarios in the Government category.

Rates 20, 40A, 50 and 60 Categories Demands: No significant mitigation measures have been proposed for these rate categories. Estimates for the changes in energy demand are limited by a lack of information on the types of energy end use equipment and/or a knowledge of the distribution of activities (for example, based on a knowledge of industrial classification – i.e., Jamaica Industrial Classification (JIC) Codes - for these customers) on which end-use demand estimates could be made. The most notable percentage reduction in CO_2 emission projections is for the street lighting (Rate 60) due to the introductions of energy efficient lighting (Figure 3.51).

Transformation: The overall changes in CO_2 emissions for transformation processes reflect the introduction of natural gas (lower CO_2 emissions in 2035 relative to 2000 for the scenarios in which natural gas is used for electricity generation). The CO_2 emissions from oil refining show no variation across scenarios since all assume the refinery upgrade takes place. The pattern for CO_2 emissions from electricity generation alone also reflects the introduction of natural gas (lower emissions in 2035 than in 2000 for scenarios *S2* NG, *S3*NG and *S3*NG NU).

Non-Energy Sector Emissions**:** The non energy sector emissions (which are ~2500 times higher in 2035 than in 2000) are dominated by the process emissions from the use of petcoke in electricity generation which is present in all scenarios. (Note that the data for the non-energy sector emissions are divided by 100.)

3.3.4 Constraints and Data Gaps

The analysis is constrained by the following:

- Although rail transportation is used (only) in the bauxite sector, information on (diesel) fuel used for rail transport was not readily disaggregated from other diesel fuel used in the sector. Rail is used to transport bauxite from some mines to plants, for transporting products (alumina and hydrate) from plants to shipping ports and for transporting materials from the ports to plants. The diesel fuel used for rail was included in that used for mining and all diesel fuel use in the bauxite and alumina sector was assumed to be for bauxite mining.
- Fuel used for domestic marine activities was not always readily available. It is believed that some of the gasoline sold in retail outlets is used for fishing and other domestic marine activities.
- Projections related to HFC emissions are not included
- Limited data was available to make projections for the sugar industry

3.4 Implementation of Mitigation Actions

This section:

- indicates the main requirements for implementing mitigation measures;
- identifies regulatory and policy gaps; and
- provides specific recommendations for implementing priority mitigation measures.

3.4.1 Main Requirements for Implementation of Mitigation Actions

Successful implementation of the mitigation measures will *inter alia* depend on:

- Provision of incentives/disincentives for the development and use of innovative technologies that improve/worsen efficiency;
- Implementation of energy related policies that support the goals of the national energy policy, namely, the biofuels, waste-to-energy, and carbon emissions trading policies;
- Creation of relevant legislation to support investments in efficiency in energy-intensive sectors such as transport and bauxite;
- A review of previous and existing demand side management programmes for performance, strengths and lessons learned;
- Stronger institutional capacities in the energy and environment sectors;
- Development of programmes designed to influence market behaviour towards more efficient use in energy across all sectors;
- Development of mechanisms to efficiently share energy related information and for public and private sector entities to collaborate on energy related projects;
- Establishment of a system to identify and replace old inefficient electricity equipment and (especially) generating units/plants with more fuel efficient and cost efficient technologies and plants;
- Promotion of strategic partnerships between the public and private sectors to finance and develop energy diversification projects; and
- Introduction of national vehicle emission standards and regulations to reduce vehicular emissions and promote introduction of cleaner transportation fuels (especially CNG).

As noted in section 3.1.3, Vision 2030 provides the context and goals for national development and the National Energy Policy 2009-30 provides the framework within which the mitigation measures indicated in S2 and S3 will take place. The Energy Policy presents a range of options and strategies for energy conservation to which the government is committed to pursue over the short, medium and longer term. It also identifies fuel diversification (with explicit targets) among the key goals to improve energy security and reduce energy costs.

Some of the specific strategies included in the Energy Policy that will facilitate the mitigation measures in scenario groups *S2* and *S3* are as follows.

- finalizing the energy efficiency and conservation policy;
- creating relevant legislation to support required investments in energy efficiency;
- infusing energy conservation issues into relevant sectoral policy development (e.g. tourism, health, and water policies);
- implementing a public education programme to encourage energy conservation;

- providing incentives/disincentives for the use of innovative/clean technologies in power generation, mining, and manufacturing to improve energy efficiencies;
- promulgating the energy efficient building code;
- introducing national vehicle emission standards;
- promoting greater vehicle fuel efficiency;
- promoting imports of more fuel efficient vehicles;
- levying taxes on petrol at appropriate levels to encourage conservation;
- providing adequate infrastructure for transition to alternative energy vehicles;
- improving infrastructure and enforcing maximum axel weight standards;
- increasing mass transit opportunities and utilization; and
- introducing financial incentives for solar technologies in the public and private sectors.

CERE will also facilitate private sector involvement to implement projects in the areas of hydropower, wind, solar, biomass and waste-to-energy.

The National Energy Policy 2008-2020 and Vision 2030 Jamaica: National Development Plan places a high priority on diversifying the country's energy mix and increasing the percentage contributed by renewables. The policy envisages that the supply mix will have marked changes by 2012 when petroleum is expected to represent 67 percent of the mix, natural gas 15 percent, petcoke/coal 5 percent and renewables 12.5 percent. By 2030, the share of petroleum in the supply mix is expected to be only 30 percent, with natural gas accounting for as much as 42 percent of the mix and renewables 20 percent.

3.4.2 Institutional and Policy Gaps Affecting Implementation of Mitigation Actions

Various regulatory, policy and coordination gaps exist in the energy sector. The 2009-30 Energy Policy clearly articulates these gaps and includes strategies to fill most of them. Some of the critical gaps that affect implementation of mitigation measures are highlighted below.

<u>Carbon Trading:</u> The draft Carbon Trading Policy includes a proposal to name the designation of the Designated National Authority (DNA) and to "*secure a sustained source of funding to support the provision of DNA related activities and services".* However although the policy recognises that absence of an institution/agency and a Clean Development Mechanism (CDM) governance structure, it does not clearly articulate the nature of the institution or agency that will house the DNA and its activities, e.g., whether or not any legislation will be needed; how the DNA office would be staffed; a timeline for its establishment; and the governance structure surrounding the DNA office.

As of 2009, the Wigton Wind Farm is the only project in Jamaica that is engaged in carbon trading. The draft policy recognises that additional capacity is needed to successfully take advantage of CDM opportunities. Since there were several potential projects in 2009 that could benefit from carbon trading, it is considered essential that this policy be implemented with great urgency.

<u>Other Policy and Regulatory Gaps</u>: Some of challenges in the energy sector include legislation that lacks adequate enforcement provisions and clearly articulated policies or protocols to address: the pricing of electricity and petroleum products; decision making about retiring or mothballing old inefficient electricity generation plants; tax and pricing structures for road users; how to (better)

address electricity system losses; and the development of renewable generation capacity. This has resulted in incremental decisions and has limited the introduction of diverse sources of energy and providing integrated monitoring and enforcement of regulations. As of 2009, there were also no legislative provisions for the net metering, carbon trading (as discussed above) or energy efficiency standards, although it is envisaged that these will be addressed as the 2009-30 National Energy Policy is implemented.

Coordination among energy sector stakeholders: The stakeholders involved in the implementation of mitigation measures span the gamut of public and private sector agencies and institutions as well as the general public. Coordination of mitigation activities and communication of vital information to and among these stakeholders will be vital. As of 2009, there were no formal interagency bodies or other mechanisms that coordinated mitigation activities between various agencies or that facilitated information flow.

Data collection and information: In general, various pieces of legislation include provisions that require reporting of fuel sales, electricity generation parameters and emissions and for acquisition of production and other "activity data" that are needed for estimating emissions and for planning purposes. Data on historical electrical energy use and fuel consumption are collected by various entities, including STATIN, PIOJ, JPS, OUR, NEPA, MTW, and MEM.

There are, however, critical gaps in the collection of information that would allow forecasting of energy and fuel consumption. Recently MEM has been engaged in energy forecasting but it appears that the effort is constrained by the lack of suitable data.

Notwithstanding the collection of historical data, the energy sector is not effectively supported by databases that are sufficiently precise to enable analysis, forecasting, and overall management of the sector. There also are significant delays in accessing reliable information. This has adverse effects on the ability to plan and make informed decisions.

The annual data compiled by STATIN in the decanal censuses and annual surveys of living conditions (e.g., ESSJ and JSLC reports) provide some of the data required for forecasting purposes based on analysis of historical trends. The JSLC surveys include good data on penetration of household electrical appliances and other amenities. Similar survey data that would be useful for estimating electricity consumption for non-residential sectors are not available. For example, a recent survey of residential energy end use was a missed opportunity to obtain energy intensity data for the residential sector.

Enhancement of the survey approach is needed so that energy intensity data can be obtained on a routine basis. Specific examples include the enhancement of the JSLC surveys to include collection of information on the age ranges and numbers in each household of selected high energy consuming appliances (e.g., refrigerators, television sets, and air conditioners). The approaches used in the US Residential Energy and Consumer Survey (RECS) or National Resources Canada (NRCAN) residential energy end use surveys would be suitable and could be easily adapted.

Since nearly all electrical appliances and equipment are imported, enhancement of the import classification would be useful to clearly distinguish between various categories of appliances (based on technology and ranges of energy use). Examples are as follows:

- Motor vehicles – to distinguish fuel used (i.e., diesel, gasoline, CNG, hybrid, electricity, etc.);

- Refrigerators (range in SEER value, refrigerant (HC or HFC));
- TVs (based on technology and/or energy intensity).

While various energy sector projects and programmes have been planned over the years, few were undertaken and there has been limited coordination of activities and timeliness in implementation of projects. Additionally, over the years, while some emphasis has been placed on the promotion of energy conservation in commercial sectors and industries such as tourism, the emphasis was not sustained and pilot projects (such as the Environmental Audits for Sustainable Tourism) were not effectively institutionalized across other sectors.

Although there have been least-cost (electricity) expansion plans (LCEPs), the expansions that have taken place have been determined by expediency and external factors have, in some cases, driven the decision making process.

There have been several sectoral plans or policies (e.g., tourism, transport, industry) but, until recently[25], there was nominal effort directed at national or sectoral energy (apart from the electricity generating sector) or emissions forecasting. For example, there appears to be little if any reliable national or sectoral energy demand projections (and hence potential savings from energy conservation initiatives for example in the tourism sector or among JPS Rate 40 and 50 consumers). In the case of electricity generation, the forecasting of electricity consumption among various rate categories was based on macroeconomic data rather than on knowledge of end use equipment.

It is to be noted that information on more immediate or shorter term energy requirements is sometimes included in environmental impact assessments and could also be included in NEPA's permit applications.

Low levels of research in the energy sector can also be identified as a gap, resulting in low levels of adoption and adaptation of new and emerging energy technologies, improvements in energy infrastructure, and appropriate legislation.

There is also a lack of a comprehensive and sustained public education programme that would encourage Jamaicans to use energy wisely and to aggressively pursue opportunities for conservation and efficiency. As a result of this, the Jamaican public has a relatively low level of awareness of the importance of energy and its use in their daily lives and the contribution that each person can make to the responsible and efficient use of this vital resource. This low level of awareness also could explain the low intensity of use of solar energy for water heating in Jamaican households.

3.4.3 Recommendations

For some countries, particularly developed countries with emission reduction targets, energy policy is linked to or framed within the context of climate change mitigation and the move towards a low carbon economy. Although developing countries, including Jamaica, do not have emission reduction targets, "no regrets" mitigation actions such as energy conservation and development of renewable

[25] MEM is in the process of preparing national energy forecasts using the ENPEP model but results are not yet available.

energy sources can have positive impacts in terms of economic, social, and environmental considerations.

The recommendations below are focused on improving the enabling environment and building institutional and technical capacities to encourage adoption of suitable energy conservation/GHG mitigation technologies and to fill data gaps that will facilitate cost-effective energy use and implementation of GHG mitigation measures.

Enabling Environment

Improving the enabling environment within which GHG mitigation and other energy sector activities take place will entail streamlining some legislation or policies and in some cases additional legislation. These include the following:

- *Strengthen regulations so there are adequate enforcement provisions and clearly articulated policies or protocols* that: address the pricing of electricity and petroleum products; improve decision making about retiring or mothballing inefficient electricity generation plants; (better) address electricity system losses; and develop renewable generation capacity;
- *Develop and implement a regulatory framework to allow carbon trading to take place.* This should include legislation establishing the DNR and associated entities, and specification of the trading modalities for local and international entities (e.g., licensing, certification or regulation of such entities, owning Certified Emission Reductions and Verifiable Emissions Reductions, etc.);
- *Establish an enabling environment to encourage local and foreign financing of innovative energy projects, especially in renewables*. This could entail developing policies and programmes that will encourage use of biogas and solar heaters as well as other alternate energy sources such as photovoltaic systems. These could, for example, entail revolving loans and/or import duty concessions and incentives for energy efficiency improvements;
- *Implement incentives that will encourage tertiary level institutions to develop research programmes for the application and implementation of renewable energy projects;*
- *Adapt/adopt or develop energy efficiency standards for consumer and industrial electrical equipment* (e.g. the Energy Star programme) and base import duties for such equipment in part on energy efficiency standards;
- *Introduce national motor vehicle emission standards and regulations;*
- *Develop regulations and safety standards in anticipation of the introduction of CNG infrastructure and CNG use in industry and in vehicles;*
- *Revise the bases for tax/customs duties* so that they are based on vehicle weight class and fuel type (not cc rating);
- NEPA in collaboration with MEM and PCJ should include the *provision of projected electrical energy and fuel use and associated technologies and appropriate benchmarking information as a requirement in selected permit applications and environmental impact assessments*. In order to focus attention on energy conservation, NEPA should rename the EIA as an Environmental and Energy Impact Assessment (EEIA);
- *Make use of the energy efficiency fund to increase energy projects*, such as those related to renewable energy;
- *Implement the building code*.

Capacity-Building Needs

Capacity building in energy sector institutions will be required if mitigation measures are to be effectively implemented.

Capacity building needs in the public sector centres on institutional arrangements for the collection, compilation, reporting and analysis of energy information and for public education.

Implementation of private sector measures requires increased private sector technology awareness and capability and an environment that facilitates and encourages investment for implementation of mitigation measures. Public sector agencies with regulatory or other responsibility for the energy and environment must also be aware of the technologies, be able to assess them and to develop policies that are responsive to private sector and national needs.

The following specific capacity building needs have been identified:

- Enhanced capacity to compile GHG (and other) emission inventories and the capacity to perform energy and GHG emissions forecasting/modelling;
- Development of an energy information clearing house;
- Staff trained to perform functions of the DNA and the supporting institutions (e.g., National Carbon Trading Promotional organization);
- DNA institutions identified and/or established and any necessary legislation enacted (e.g., to enable certification or licensing of trading modalities);
- Role of the Energy Efficiency Unit within the Petroleum Corporation of Jamaica expanded to provide technical assistance for ECE initiatives in the public and private sectors;
- Regulatory agencies provided with enforcement powers to improve the efficiency of the system and comply with established benchmarks, procedures and standards;
- Stronger links with the energy sector and academic institutions developed to drive the adoption and adaptation of new technologies in the energy sector;
- Capacity of local companies developed to improve their processes and energy efficiencies and to take advantage of carbon trading opportunities.

Adoption of Clean and Energy Efficient Technologies

- *The identified renewable energy projects for electricity generation as of 2009 are not likely to meet the targets for renewables set in the 2009-30 Energy Policy*. Although there have been several studies on cogeneration in the sugar industry, firm plans remain elusive. It has been estimated that increasing sugar cane production to 3.36 million tonnes cane could provide an additional 47.4 MW for sale to the grid[26]. A more modest target for increased sugar cane production to yield an additional 30 MW would likely be more achievable[26]. Other biomass projects are in the conceptual stages but need further development. The inclusion of additional cogeneration in the sugar industry

[26] A crude estimate would be to increase the 2008 amount of 1.65 million tonnes sugar cane milled to 2.2 million tonnes.

with sale of electricity to the grid would help to achieve the energy policy targets for renewable;

- *Develop capacity to facilitate greater energy efficiency in the bauxite and alumina industry and the manufacturing sector* (Rate 40 and Rate 50 JPS customers). Initiatives such as the recently announced partnership between JPS and NWC could be applied an a sectoral basis (once suitable information is available);
- *Engage in research towards adoption and adaptation of new and emerging technologies and improvements in energy infrastructure*. This should include distributed energy generation from solar and wind energy and low grade heat for cooling/air conditioning;
- *Implement incentives/disincentives to enable the development and use of innovative technologies to improve energy efficiencies* in all sectors and in households;
- *Research and develop alternative fuels for the transport sector*, including the use of biofuels and CNG when it becomes available;
- *Encourage the use of solar powered water pumping* by the NWC; mandate that all new hot water installations be solar in all public buildings; and promote more widespread use of solar water heating in hotels;
- *Promote the adoption of solar powered cooling/air conditioning,* especially in the hotel/tourism sector;
- *Implement demand-side energy management programmes*, including the use of energy-efficient appliances, equipment, and building designs; setting and enforcing standards for public sector organizations; and public awareness and educational programmes.

<u>Address Data and Information Gaps</u>

- Improve the motor vehicle fleet database (e.g., ensure correct assignment of fuel type; add off road categories, weight units; clearly distinguish between non-motorised trailers and motorised trailers; add allowance (categories) for hybrid and CNG vehicles. This could be achieved by quality assurance checks during data entry and use of databases with manufacturers' specifications);
- Compile statistics for annual vehicle kilometres travelled (VKMT)[27] through periodic surveys or routinely collect and record odometer readings during vehicle inspections for certificates of fitness;
- Develop mechanisms that would facilitate or require fleet management companies to report VKMT and other general non-confidential vehicle data;
- Code JPS customers (at least the Rate 40 and 50 customers) by JIC and require reporting of energy use statistics by JIC accordingly. This type of information will inform the design of appropriate end use surveys in the commercial/manufacturing sectors and in planning/forecasting demand;
- Survey industrial and commercial customers for end use equipment;
- Conduct periodic surveys for charcoal and wood use;
- Conduct proper residential energy use survey in conjunction with data from JPS smart meters;
- Compile data on appliance imports or sales for refrigerators;
- Assess impact of distributed electricity generation and water storage and if appropriate develop a suitable program to promote its implementation;

[27] A study is currently under way

- Develop and sustain public education on energy efficiency and conservation;
- Review the sustainable development and energy conservation curriculum needs throughout the (primary, secondary and tertiary levels) in the educational system and enhance the curriculum accordingly.

Appendix 3.1: Scenarios for the Demand and Non-Energy Sector Effects

Category	Reference (REF)	Scenario 2 (*S2*)	Scenario 3 (*S3*)
Key Assumptions			
Population	Growth at 0.47% declining to 0.25% in 2030	Growth at 0.38% declining to 0.25% in 2030	Growth at 0.38% declining to 0.0% in 2030
Household size	Constant at 3.33	From 3.33 in 2008 to 3.20 in 2015 to 3.15 in 2035	From 3.33 in 2008 to 3.20 in 2015 to 3.10 in 2035
No. of households	Population/household size	Population/household size	Population/household size
GDP 2003 J$	PIOJ data for 2009, 2010, 2012, 2015 and 2030	Same GDP growth to 2020 as Reference. Growth increasing by 1% between 2020-30 (i.e., from 3 to 4% and constant after 2031-35)	Same GDP growth to 2020 as Reference. Growth increasing by 2% between 2020 -30 (i.e., from 3 to 5% and constant after 2031-35)
GDP growth rate	0% in 2009, 1% in 2010; 3% in 2012-15; to 4% in 2030	0% in 2009, 1% in 2010; 3% in 2012; 4% in 2015; 4.5% in 2035	0% in 2009, 1% in 2010; 3% in 2012; 4% in 2015; 5.0% in 2035
Demand			
Households			
No. of households	Number of households based on population and household size (above)	Number of households based on population and household size (above)	Number of households based on population and household size (above)
Residential (Rate 10) Customers	Appliance penetration for Rate 10 customers assumed the same as household penetration from JSLC	Appliance penetration for Rate 10 customers assumed the same as household penetration from JSLC	Appliance penetration for Rate 10 customers assumed the same as household penetration from JSLC
Residential (Rate 10) Customers	Rate 10 customers increase from 523,728 in 2008 to 780,951 in 2035. Customer/Household ratio increases from 0.648 in 2008 to 0.860 in 2035	Rate 10 customers increase from 523,728 in 2008 to 800,850 in 2035. Customer/Household ratio increases from 0.648 in 2008 to 0.860 in 2035	Rate 10 customers increase from 523,728 in 2008 to 808,290 in 2035. Customer/Household ratio increases from 0.648 in 2008 to 0.8825 in 2035
Refrigeration	Penetration (saturation) increases from 2008 level (77.4%) to 92% in 2030. No energy efficient refrigerators. Note – imports account for ~0.5% of stock of refrigerators.	Penetration (saturation) increases from 2008 level (77.4%) to 92.5% in 2035. Energy efficient penetration increases from 0 to 5% in 2015; 8.5% in 2020; 12% in 2025; 19% in 2035. Energy efficiency improves by 15% in 2025 for existing and energy efficient fridges.	Penetration (saturation) increases from 2008 level (77.8%) to 95% in 2035. Energy efficient penetration increases from 0 to 9.5% in 2015; 16.5% in 2020; 21.5% in 2025; 31.5% in 2035. Energy efficiency improves by 15% in 2025 for existing and energy efficient fridges.

Lighting	Keep current mix of technologies (incandescent (17.7%), CFLs from 74% in 2008 to 80% in 2015 based in existing programs. No LED; Kerosene decreases from 6.1% in 2008 to 1% in 2035	CFLs from 74.13 to 90% in 2015 and incandescent to decrease from 17.87 to 10% by 2015; LED from 0 to 2% in 2015 and 5% in 2035; Kerosene decrease from 6.3 to 3% in 2015	Add CFLs to 95% saturation by 2015 (from 74.13 to 95%) and incandescent to decrease from 17.87 to 5% in 2015 and 0% by 2035; LED increases from 0 to 5% in 2015 and to 10% in 2035; Kerosene decrease from 6.3 to 1% in 2015
Cooking	LPG from 89.3% in 2008 to 95% in 2030; Electric stoves from (2.5% to 10% in 2030; charcoal and firewood flat	LPG from 89.3% in 2008 to 95% in 2020; Electric stoves from (2.5% to 10% in 2020; charcoal and firewood flat	LPG from 89.3% in 2008 to 95% in 2020; Electric stoves from (2.5% to 10% in 2020; charcoal and firewood flat
Fans	Assume current penetration rates (68.1%) remains flat	Assume current penetration rate (68.1%) increases to 80% in 2015. Energy efficiency improves by 15% in 2025	Assume current penetration rates (68.1%) goes to 90% in 2015 Energy efficiency improves by 15% in 2020
Stereo	Assume 2008 penetration rates and energy efficiency	Penetration rates from 35.8% to 50% in 2020. Energy efficiency improves by 5% in 2020	Penetration rates from 35.8% in 2008 to 60% in 2020. Energy efficiency improves by 10% in 2020
Air Conditioners	Keep current penetration rate (2.9%) and assume no efficient or HC-based ACs	Penetration rates for existing from 2.9% to 10% in 2020; 5% in 2035. Efficient ACs 0% to 10% in 2020; 20% in 2035. HC from 0 to 5% in 2020 and to 20% in 2035. Energy efficiency improves by 15% in 2025 for existing; by 25% in 2035 for efficient ACs and by 16% in 2035 for HC ACs	Penetration rates for existing from 2.9% to 10% in 2015, 12% in 2020, 10% in 2025, and 0 in 2035. Efficient ACs 0% to 15% in 2020; 20% in 2035 and 25% in 2030. HC from 0 to 10% in 2020 and to 25% in 2035. Energy efficiency for existing ACs improves by 15% in 2025, for HC ACs by 16% in 2035 and by 25% for efficient ACs by 2035
Computer equipment	Assume current (2008) penetration rate (15.5%) remain the same	Penetration rates from 15.4% to 30% in 2020 and 60% in 2035. Energy efficiency improves by 15% in 2025	Penetration rates from 15.4% to 15% in 2020 and 80% in 2035. Energy efficiency improves by 15% in 2020 and further 10% by 2035

Washing Machines	Penetration rate for existing machines increases from 29.74% to 35% in 2020 and 50% in 2035 (no energy efficient machines)	Penetration rate for existing machines decreases from 29.74% to 22% in 2020 and 20% in 2035. Energy efficient machines penetrate to 3% by 2015; 8% by 2020 and to 30% in 2035. Energy efficiency for existing machines improves by 15% by 2020 and for efficient machines by 50% by 2020	Penetration for existing machines from 29.74% to 27% in 2020 and 15% in 2035. Energy efficient machines to 3% in 2015; 13% by 2020 and 52% by 2035. Energy efficiency for existing machines improves by 20% by 2020 and for efficient machines by 50% by 2020
TV	Penetration rate increases from 89.5% to 95% by 2015. Energy efficiency – no change Note: Insufficient data on types (LED, plasma etc.) of TVs – so assumed overall group.	Penetration rate increases to 95% by 2015. Energy efficiency improves by 4% by 2012 and by 33% in 2025 (relative to 2008 values)	Penetration rate increases to 95% by 2015. Energy efficiency improves by 4% by 2012 and 44% in 2025 (relative to 2008 values)
Clothes iron	Saturation from 92% in 2008 to 95% by 2035. No change in energy efficiency	Saturation to 95% by 2035. Energy efficiency improves by 15% in 2020	Saturation to 95% by 2030. Energy efficiency improves by 20% in 2020
All other	Assume current penetration rates remain the same. Energy efficiency – no change	Assume current penetration rates remain the same. Energy efficiency improves by 10% in 2025	Assume current penetration rates remain the same. Energy efficiency improves by 15% in 2025
Industry			
Cement Clinker	2009 value from CCCL; 2010 at 0.9 Million tonne or 900 ktonne and thereafter growing at 30% of GDP growth (including assumed export market (increasing from 132 ktonne in 2011 to 181 ktonne in 2035) [1.181 Million tonne in 2035] Note: kilns at capacities after 2035. Kiln 4 reopened 2011 and Kiln 3 permanently closed.	2009 value from CCCL; 2010 at 900 Mt and thereafter growing at 35% of GDP growth rate (including assumed export market (115 ktonne 2009-2020; 110 ktonne to 2021; 100 ktonne to 2025; decreasing to 60 ktonne 2035) [1.280 Million tonne in 2035]. Note: kilns at capacities in 2035. Kiln 4 reopened (2011) and Kiln 3 permanently closed.	2009 value from CCCL; 2010 at 900 Mt (17%) and thereafter growing at 45% of the GDP growth (including assumed export market (120 ktonne to 2012; 100 ktonne in 2013 decreasing to 20 ktonne in 2025 then 0 ktonne in 2032) [1.3 Million tonne in 2031 through 2035]. Note: kilns at capacities in 2031. Kiln 4 reopened (2011) with improved efficiency. Kiln 3 permanently closed.
Cement Mills	Based on clinker production	Based on clinker production	Based on clinker production
Bauxite Mining	Bauxite linked to alumina production based on existing average ratios of bauxite to alumina at each alumina plant	Bauxite linked to alumina production based on existing average ratios of bauxite to alumina at each alumina plant	Bauxite linked to alumina production based on existing average ratios of bauxite to alumina at each alumina plant

Bayer Process	Alpart reopens in 2012 at same capacity (1.625 million tonne alumina) as in 2008 (ramping from 75% in 2012 to 95% capacity in 2013). No Jamalco JU3 expansion but 5% capacity increase (from 1.425 Mt to 1.5 million tonne alumina in 2010). Note: assumed production at 95% capacities. Windalco Kirkvine closed. Windalco Ewarton opens at 75% of original capacity in 2012, 90% in 2013 and 95% in 2014 and thereafter. St Ann Bauxite – 4.2 million tonne bauxite in 2010 then up to 4.452 million tonne thereafter. HFO used in all plants.	Alpart reopens in 2012 at same capacity as in 2008 (ramping from 75% in 2012 to 95% capacity in 2013). Jamalco expansion 1.425 to 2.8 million tonne alumina in 2014. Windalco Kirkvine closed. Windalco Ewarton expanded to capacity equal to previous Kirkvine and Ewarton capacities in 2013 (ramping from 75% in 2013 to 95% in 2014) [0.975 to 1.235 million tonne alumina]. St Ann Bauxite – 4.2 million tonne in 2010 then up to 4.452 million tonne thereafter. Coal or CNG at Jamalco in 2013 and at Alpart and Ewarton in 2015.	Alpart reopens in 2012 at same capacity (ramping from 75% in 2012 to 95% capacity in 2013). Jamalco expansion 1.425 to 2.8 million tonne alumina) in 2014. Windalco Kirkvine reopened in 2015 at 500 t/y. Windalco Ewarton expanded to capacity equal to previous Kirkvine and Ewarton capacities in 2013 (ramping from 75% in 2013 to 95% in 2014) [Total Windalco from 0.975 in 2012, 1.17 in 2013, 1.235 in 2014, 1.71 million tonne in 2015.] New alumina plant added in 2015 (2.0 million tonne alumina up to 2.5 million tonne in 2020 and 3.0 million tonne in 2025). All alumina and associated lime plants use CNG except alumina kiln at new plant which uses CNG or gasified coal. St Ann Bauxite – 4.2 million tonne in 2010 then up to 4.452 million tonne thereafter. Coal or CNG at Jamalco in 2013 and at Alpart and Ewarton in 2015 and new plant in 2015.
Lime Kilns	Lime linked to bauxite and alumina production based on existing average ratios of bauxite to lime at each plant. HFO in lime kilns.	Lime linked to bauxite and alumina production based on existing average ratios of bauxite to lime at each plant. Coal or CNG in lime kilns.	Lime linked to bauxite and alumina production based on existing average ratios of bauxite to lime at each plant. Assume energy efficiency for new lime plants at 5GJ/tonne lime. Coal or CNG in lime kilns.

Alumina Kilns	See above for production levels. Not boilers for Bayer process and HFO in all alumina kilns.	Alpart reopens in 2012 at 80% of previous capacity, going to 100% capacity in 2013 (4,128 Mt to 5,156 Mt bauxite) using LNG. Jamalco JU3 expansion 1,710 Mt to 2,000 Mt alumina (4,419 Mt to 6,978 Mt bauxite) in 2014 with LNG and coal options. Windalco Kirkvine closed. Windalco Ewarton expanded to capacity equal to previous Kirkvine and Ewarton capacities in 2013 (ramping from 80% in 2013 to 100% in 2014). Coal or CNG at Jamalco in 2013 and at Alpart and Ewarton in 2015. CNG or Syngas in kilns	Alpart reopens in 2012 at 80% of previous capacity and going to 100% capacity in 2013 (4,128 to 5,156 Mt bauxite). Jamalco JU3 expansion 1,710 Mt to 2,000 Mt alumina (4,419 Mt to 6,978 Mt bauxite) in 2014. Windalco Kirkvine closed. Windalco Ewarton expanded to capacity equal to previous Kirkvine and Ewarton capacities in 2013 (ramping from 80% in 2013 to 100% in 2014). One new alumina plant at 1,500 Mt alumina/y in 2015 at 75% then at 95% in 2016. CNG or Syngas in kilns.
Energy intensity bauxite/alumina	Mining: Used available historical data for Alpart, St Ann Bauxite and Windalco and then averaged for Jamalco. Boiler (Bayer): Used historical data to 2007. Alumina kilns: Used historical data to 2007. Lime kilns: Used available historical data for Alpart, Windalco. Assumed same for Rugby	Mining: Used available historical data for Alpart, St Ann, and Windalco and then averaged for Jamalco. Continued value for 2007 out to 2035. Boiler (Bayer): Used historical data to 2007. Continued values for 2007 out to 2035. Note: no mitigation or improvement in energy/tonne alumina. Alumina kilns: Used historical data to 2007. Continued value for 2007 out to 2035. Lime kilns: Used historical data for Alpart, Windalco. Assumed same for Rugby. Continued value for 2007 out to 2035. New lime kiln for Windalco and new plant at 5 GJ/tonne	Mining: Used available historical data for Alpart, St Ann, and Windalco and then averaged for Jamalco. Continued value for 2007 out to 2035. Boiler (Bayer): Used historical data to 2007. Continued values for 2007 out to 2035 (need better values for upgraded Alpart and Windalco plants to reflect improvement in energy/tonne alumina). Alumina kilns: Used historical data to 2007. Continued value for 2007 out to 2035. Lime kilns: Used historical data for Alpart, Windalco. Assumed same for Rugby. Continued value for 2007 out to 2035. New lime kiln for Windalco and new plant at 5 GJ/tonne.
Sugar SCJ	No data – assumed 2008 production levels continue	No data – assumed 2008 production levels continue	No data – assumed 2008 production levels continue
Sugar Private	No data – assumed 2008 production levels continue	No data – assumed 2008 production levels continue	No data – assumed 2008 production levels continue

Other Manufacturing	BOE growth at 1%/year	BOE growth at 1.2%/year	BOE growth at 1.5%/year
Municipal Rate 60	2.4% growth to 2014 and 3% thereafter	2.4% growth to 2014 and 3% thereafter	2.4% growth to 2014 and 3% thereafter. Introduction of LED street lighting to 5% in 2015 and 50% in 2035
Rate 20	-1.18%, -1.18%, -0.44%, 0.56%, 1.14% and 1.12% growth rates between 2008-13 and 1% thereafter	Same as Reference to 2013 and 1.5% thereafter	Same as Reference to 2013 and 2.0% thereafter. Energy efficiency improves by 20% in 2035
Rate 40A#	-0.99%, -0.99%, 2.88%, 4.76% and 4.53% between 2008-13 and 2% thereafter. No change in energy efficiency	Same as Reference to 2013 and 2.5% thereafter. Energy efficiency improves by 10% between 2009-35	Same as Reference to 2013 and 3.0% thereafter. Energy efficiency improves by 20% between 2009-35.
Rate 50	Growth rates: 2008,-3.15%; 2010, -2.92%; 2011, 0.42%; 2012, 3.05%; 2013, 2.83%; 2014 and thereafter, 2.0%	Same as Reference to 2014 and thereafter, 2.5%	Same as Reference to 2014 and thereafter, 3.0%
Rate 50 Other	-1.7% growth to 2014 and 0.25% thereafter	-1.7% growth to 2014 and 0.5% thereafter	-1.7% growth to 2014 and 1.0% thereafter
Rate 50 UWI		Need additional UWI Data. Assume further 150 MWh reduction from AC and 50 MWh from other initiatives 2009-13	Need additional UWI Data. Assume further 350 MWh reduction from AC and 75 MWh from other initiatives 2009-13
Government	No change	10.4% reduction in overall energy by 2014. Flat thereafter.	15.9% reduction in overall energy by 2014.
NWC	Note - no mitigation initiatives	NWC Phase 1. Assumed 5%/year for 2009-11 for a total of 15% reduction	NWC Phase 2. Assumed 10%/year in 2012-13 for a total of 20% reduction
Hospitals	Note - no mitigation initiatives. Assumed average electricity over 2000-08 for future years.	Hospital AC: 11.8% 2011+5y Hospital Lighting: 0.54% 2011+2y Hospital Other: 3.96% 2012 +3y Hospital Refrigeration: 5% 2013 +5y Hospital Fuels: 1.22% reduction Total reduction in electricity: 14.83%	Hospital AC: 2.29% 2016 +5y Hospital Lighting: 3.79% 2013 +4y Hospital Other: 5.66% 2015 +4y Hospital Refrigeration: 0.41% 2018 +3y Total reduction in electricity use: 12.15%
Other govt (includes all govt except NWC and hospitals)	Note - no mitigation initiatives	3% reduction/year for 2010-14 (inclusive) in electricity [equivalent to 14.2% reduction by 2014]	Additional 5% reduction in electricity use by 2014
Transport			
Growth in fleet	1% to 2012, 0.5%to2020, 0.1% to 2035	1.5% to 2012, 1.0% to2020, 0.1% to 2035	2.0% to 2012, 1.5% to 2020, 0.1% to 2035

E10 market penetration	100% by 2010	100% by 2010	100% by 2010
E20, E25, E30 or E85 introduction	No initiatives	No initiatives	No initiatives
Low sulphur gasoline & diesel	2014	2014	2014
Biodiesel introduction	None	To be determined	To be determined
Impact of cross country highways (Highway 2000, North Coast Highway)	Kingston Bushy Park and Montego Bay/ Port Antonio completed; Spanish Town Ocho Rios in 2012; Sandy Bay Four Paths Four Paths Williamsfield (2020)	As for Reference	As for Reference
JUTC & MBM	None	10% of JUTC and MBM fleet by 2020 and 20% by 2035	15% of JUTC and MBM fleet by 2020 and 30% by 2035
CNG taxi & passenger cars	None	0.1% of LDGV by 2020 and 0.2% by 2035	0.2% of LDGV by 2020 and 0.4% by 2035
CNG	None	5% of fleet by 2020	10% of fleet by 2020
Other transport – buses HDGV	None	0.3% by 2020; 0.6% by 2035 (1000 and 2000 vehicles)	0.6% by 2020; 1.2% by 2035 (2000 and 4000 vehicles)
Other buses and HDDV	None	1% by 2020; 2% by 2035 (200 and 400 vehicles)	2% by 2020; 4% by 2035 (400 and 800 vehicles)
Growth in air traffic	Assume 5% growth in LTOs	Assume 7% growth in LTOs	Assume 9% growth in LTOs
Non-Energy Sector Effects			
Agriculture			
Increase in sheep population	No new initiatives	Herd needed to replace 80% of imports by 2015 has negligible impact on CH_4 emissions	Herd needed to replace 80% of imports by 2015 has negligible impact on CH_4 emissions
Increase in other animal population	No new initiatives	Negligible impact on CH_4 emissions (for local pork, beef production)	Negligible impact on CH_4 emissions (for local pork, beef production)
Rice	No new initiatives beyond current	25,000 ha by 2011. Increasing by population growth rate	25,000 ha by 2011. Increasing by population growth rate
Biogas initiatives	No new initiatives	Need additional data	Need additional data

Landfill emissions	Population growth projections	Population growth projections (less EFW waste)	Population growth projections (less EFW waste)
Forestry			
Program to reduce deforestation rate to zero by 2013	No new initiatives	Program to reduce deforestation rate to zero by 2013	Program to reduce deforestation rate to zero by 2013
Program to plant trees (reforestation)	No new initiatives	No measurable effect so excluded	No measurable effect so excluded
% increase in sustainable forest harvesting (target to be determined)	No new initiatives	No measurable effect so excluded	No measurable effect so excluded
Industry			
Cement	Based on clinker production	Based on clinker production	Based on clinker production
Lime	Based on lime production	Based on lime production	Based on lime production
Coke	Based on Pet Coke project	Based on Pet Coke project	Based on Pet Coke project
Biogas generation initiatives	Based on existing number of biogas units remaining the same	Need data available	Need data available

[#] JPS Rate 40 adjusted to avoid double counting of Petrojam and CCCL electricity use and also to include the JPS Other class with 3 customers – and renamed as Rate 40A

Appendix 3.2: Scenarios for Transformation and Energy Resources

Transformation Category	Size	Reference (REF)	Scenario 2 (*S2*)	Scenario 3 (*S3*)
Transmission & Distribution				
Electricity Distribution		Losses reduced from 23.8% to 16.3% in 2014	Losses reduced from 23.8% to 16.3% in 2014	Losses reduced from 23.8% to 16.3% in 2014
Oil refining				
Oil Refining		Upgrade in 2014. Any product shortfall met by imports; Petcoke, VGO and sulphur by-products	Upgrade in 2014. Any product shortfall met by imports; Petcoke, VGO and sulphur by-products	Upgrade in 2014. Any product shortfall met by imports; Petcoke, VGO and sulphur by-products
Electricity Generation				
Bogue Gas Turbines	179.3 MW	Continue		
Bogue GT6 & GT8		Add 4 MW to each - engine installation 2010		
Bogue CGCT	40 MW	Continue		
Bogue CGCT inlet adjustment	10 MW	2009		
Bogue GT6 & GT8	8 MW	2015		
Convert Bogue to CNG	120MW		2013	
Hunts Bay Gas Turbines	32.5 MW	Continue		
Hunts Bay B6	68.5 MW	Retire in 2017	Retire in 2017	
Rockfort JPS enhancement	36 MW	Add 4 MW in 2010		
Jamaica Broilers	16 MW	Retired in 2004		
Rockfort JPS	36 MW	Continue		
Upgrade Rockfort Unit # 2	2MW	2009		
JEP	90	Continue		
JPPC	60 MW	Continue		
IPP (JEP Marcus Garvey)	60 MW	2010		
Jamalco	12.1 MW	Continue	Retire in 2014	
Old Harbour1-4	223 MW	Retire OH1 in 2015 (-30 MW) Retire OH3 and OH4 in 2018 Retire OH2 in 2017 (-60 MW)		
Hydro	21.59 MW	Continue		
Restore Constant Spring Hydro	0 MW	Restore to 0.8 MW 2009		
Maggotty hydro	6.4 MW	2013		

New hydro A	15.3 MW	None of these new hydro	2011 Spanish R (2.5 MW) 2012 Great R (8.0 MW) 2013 Martha Brae (4.8 MW)	
New hydro B	24.6 MW	None of these new hydro		2015 Laughlands (2.0 MW) 2017 Yallahs (2.6 MW) 2019 Back Rio Grande (20 MW)
Wigton	20 MW	Continue		
Munro	0.36 MW	Continue		
Wigton Wind Farm Expansion	18 MW	2011		
Pet Coke	120 MW	2014	2014	2014
Old Harbour Phase 1 Coal LNG	150 MW	2013	 2015 2015	
Old Harbour Phase 2 Coal LNG	150 MW	2013	 2015 2015	 2015 2015
Waste to Energy	65 MW		2014	
Munro wind JPS	3.0 MW	2010		
Munro School	20 MW			2018
Windalco expansion 60 MW			2015	2015
Coal or Nuclear 100 MW	100 MW 100 MW			2025 2030
New Petcoke at Cement or Bauxite plant	100 MW			2020 100 MW 2025 200 MW (total)

Appendix 3.3: MEM Energy Projects and Proposals Assigned to Mitigation Assessment Scenarios

	Project/Initiative	Implementing Agency	Status	Remarks [scenario assignment/comment]
	POLICIES			
1	National Energy Policy 2008-30	MEM	Task Force meets weekly as well as work in between meetings to deliver on very aggressive schedules. Inputs from Draft Green Paper, Prime Minister's National Energy Committee, Prime Minister's Task Force on Energy, and Public Consultation on Energy Policy Green Paper	Task Force established to fast track completion of the Energy Policy by mid June, 2009. *[Not applicable to Scenarios]*
2	Energy Conservation and Efficiency Policy 2008-22	MEM	Draft Policy was Tabled in Parliament in July, 2008 as an addendum to the (previous) Energy Policy Green Paper	*[Not applicable to Scenarios]*
3	Development of Net Metering Policy and Legislation	MEM	Petrocaribe Financing is one of the sources identified. Active participation in negotiations is ongoing through the Petrocaribe Technical Work Group on Renewable Energy. The proposed project was approved but will be implemented under a regional programme.	Appropriate legislation is required to standardize and regularize the way distributed generation sources are interconnected to the national electric grid. This will facilitate greater penetration of renewable energy sources and help to achieve government targets for fuel diversification and renewable energy development *[Not applicable to Scenarios]*
4	Carbon Policy Development	MEM/PCJ	Task Force established to develop Jamaica's position on Carbon emissions and trading	*[Not applicable to Scenarios]*
5	Bio-Fuels Policy Development	MEM/PCJ/Ministry of Agriculture	Development of Bio-Fuels Policy and Action Plan aimed at Bio-Fuels Policy Support Capacity Building for public and private sector representatives. Land research and mapping to support locally grown feedstock Font Hill Bio-Diesel experiment and pre-feasibility assessment for the national bio-diesel plan. Bio-Fuels Pricing and Taxation Study. Biomass Study	*[Biodiesel introduction as fuel; penetration to be determined. No data to allow inclusion in scenarios]*

	Project/Initiative	Implementing Agency	Status	Remarks [scenario assignment/comment]
6	Revision of GOJ Procurement Policy (some energy components)	MEM/MF&PS		Policy completed and implemented *[Not applicable to Scenarios]*
7	GOJ Policy on Environmental Stewardship (Draft Environmental Management Systems Policy)	OPM/EMD		*[Not applicable to Scenarios]*
	LEGISLATIONS, STANDARDS AND CODES			
8	Primary Legislation for the Electricity Sector	MEM/OUR	Will replace outdated legislations and acts governing the electricity sector	*[Not applicable to Scenarios]*
9	Equipment Standards and Legislation for Energy End Use Devices	MEM/BSJ	Development of Standards and codes for End Use Devices and the requisite Legislation to enforce compliance	Scenarios 2 and 3 – Assume Jamaican energy efficiencies for new appliances sold lag US or Canadian by 2 to 4 years
10	National Petroleum Standards and Codes	MEM/BSJ	Development of National Standards and Codes to regulate the Petroleum Sector	*[Not applicable to Scenarios]*
	PETROLEUM			
11	Petrojam Refinery Expansion	PCJ/Petrojam	Expansion of the Refinery from production of 35,000 bbl of oil per day to 50,000 bbl per day capacity	Petcoke Cogeneration Project to generate 120MW of electricity *[All scenarios]*
12	E-10 Storage Capacity Expansion	PCJ/Petrojam /Petrojam Ethanol	Installation of Storage facility in Western end of the island to facilitate E – 10 Roll-out	*[All scenarios after 2010 (first full year)]*
13	Oil and Gas Exploration	PCJ		*[Not applicable to Scenarios – assume none is found]*
14	Oil Trading	PCJ		*[Not applicable to Scenarios]*
15	Proposal for data exchange and technical assistance regarding oil and gas exploration activities	PCJ	PCJ is interested in establishing a program of data/information exchange and technical assistance as it relates to oil and gas exploration. Jamaica and Cuba share a similar geological history. Oil and gas exploration activities are being conducted in 12 offshore blocks in Jamaica. Cuba has made important	It is proposed that dialogue between technical personnel in Cuba and Jamaica be initiated to discuss the scope of technical (mainly geological) issues faced. A sharing of experience with regards to the administration of exploration contracts will also be welcomed. It is anticipated that such

	Project/Initiative	Implementing Agency	Status	Remarks [scenario assignment/comment]
			economic finds in its offshore acreage to the north. The strategy for fuel diversification requires that all viable options are considered. The introduction of natural gas is one option being considered for regional cooperation for its introduction/expansion in the region through Petrocaribe initiative through the working team on gas.	dialogue could take place mainly via written correspondence with the exchange of technical data by parcel post if necessary. Future work in the latter phase of this project could see the exchange of technical personnel between the two countries, if this is deemed cost effective. *[Not applicable to Scenarios]*
16	Liquefied Natural Gas (LNG)	MEM/PCJ	Development of facility to distribute LNG Secure long term contract for the supply of Natural Gas	*[Scenarios 2 and 3]*
17	Ethanol Blended Fuel (E10)	MEM/PCJ	10% Ethanol Fuel Blend introduced in the transport sector in October 2008	Full roll-out dependent on additional storage capacity installation in Western end of the island *[All scenarios after 2010 (first full year)]*
18	PETCOM Rationalization	PCJ/PETCOM	Programme to rationalize the operations of PETCOM to create a more viable business	*[Not applicable to Scenarios]*
19	Bilateral and Multilateral Relations	PCJ	Strengthen bilateral and multilateral ventures	*[Not applicable to Scenarios]*
20	Russian - Nuclear		Nuclear power barge facility	*[Scenario S3 NGNU after 2025 – but no assumption of source though]*
	ELECTRICITY GENERATION EXPANSION			
21	Petroleum Coke 120MW Plant	PCJ/Petrojam		*[All scenarios]*
22	JEP 60MW Plant	MEM/OUR		*[Reference Scenario]*
23	Compressed Natural Gas for JPS Power Plants	MEM/OUR		*[Scenarios 2 and 3]*
24	Merit Order Dispatch Study to identify an appropriate Model for Jamaica	MEM/OUR		[Insufficient cost data to allow economic dispatch to be used in LEAP]
25	National Energy Planning and Efficiency Study	MEM/Cabinet Office	ACRES Management Consulting completed study on the electricity power sector and provided a road map for developments within	Study was completed in 2007 *[Not applicable/relevant to Scenarios]*

	Project/Initiative	Implementing Agency	Status	Remarks [scenario assignment/comment]
			the sector	
26	Improvements in the Operations of JPS	OUR	Consequent to the All Island Blackout in electricity supplies on July 15, 2006, the GOJ instructed that a forensic investigation be conducted into the circumstances which led to the failure of the electricity system and how to prevent such occurrence in the future	Some recommendation implemented but others are outstanding *[Not applicable/relevant to Scenarios]*
27	Transmission and Distribution Code for JPS operations	MEM/OUR	Development of a Transmission and Distribution code in progress. A consultant is engaged by JPS to develop the Code	*[Not applicable to Scenarios]*
	ENERGY CONSERVATION AND EFFICIENCY (ECE) AND RENEWABLE ENERGY (RE) SOURCES			
28	IBD Technical Assistance for Energy Conservation and Efficiency in the Public Sector	MEM/PIOJ	Technical assistance to be executed jointly by the IDB and MEM to evaluate energy consumption within the public sector and develop plan to implement corrective measures	Work to start Q2 of FY 2009/10 *[Not applicable to Scenarios – note separate measures for hospitals, NWC and Other Govt electricity use]*
29	Technical Assistance from the World Bank	MEM	Discussions to be continued on obtaining additional assistance from World Bank to assist Jamaica with its energy challenges	Video Conference set for June 2, 2009 *[Not applicable/relevant to Scenarios]*
30	Technical Assistance from the United States Embassy	MEM	Discussions to be continued with the objective to get assistance from the US Embassy to assist Jamaica with its energy challenges	Opportunities identified in the areas of Waste to Energy, Bio-Fuels Cooperation, Renewable Energy Public Awareness, Ethanol Exports, and the Petcoke Power Plant expansion Project *[Not applicable/relevant to Scenarios]*
31	Improve lighting energy efficiency in hospitals and schools	MEM/PCJ	Project already identified and proposal submitted for Petrocaribe financing. The proposed project was approved but will be implemented under a regional programme. Energy audits already completed for 22 hospitals and 8 schools. The projected cost saving for all the hospitals is US$131,687 per year and the associated implementation cost	Replacement of T12 fluorescent tubes with T8 tubes and replacing magnetic ballasts with electronic ballasts in hospitals and schools. *[Scenarios 2 and 3]* Petrocaribe Financing is one of the possible sources identified. Active participation in negotiations is ongoing through the Petrocaribe Technical Work Team on Savings

	Project/Initiative	Implementing Agency	Status	Remarks [scenario assignment/comment]
			is US$213,235. This gives an overall simple payback period of 1.6 years. The projected cost saving for all the schools is US$3,591,464 per year and the associated implementation cost is US$5,815,500. This gives an overall simple payback period of 1.6 years.	and Efficient Use of Energy.
32	Improve energy efficiency of street lights	MEM/PCJ	Solar photovoltaic technology will be applied for powering and / or switching of street lights and for general lighting in public spaces to improve efficiency and ensure that the lights are not left on in daylight. In addition, discussions are underway with several business interests (private) that have expressed willingness to provide solar voltaic powering of street lights throughout Jamaica. A pilot project is to be commenced in the community of Portmore for which some preliminary engineering and economic analyses are been done.	Petrocaribe Financing is one of the sources identified. Active participation in negotiations is ongoing through the Petrocaribe Technical Work Group on Renewable Energy. *[Scenarios 2 & 3]*
33	Improve energy efficiency of traffic lights	MEM/PCJ	The proposed project for replacing incandescent light bulbs used for traffic signals with Light Emitting Diodes (LED) was approved for Petrocaribe financing but will be implemented under a regional programme.	Petrocaribe Financing is one of the sources identified. Active participation in negotiations is ongoing through the Petrocaribe Technical Work Team on Savings and Efficient Use of Energy. The traffic lights in Jamaica use 75 watt incandescent bulbs. When these bulbs are replaced the energy savings will be very significant. *[No data available to allow inclusion in scenarios (in Government sub-branch?]*
34	Improve energy efficiency in the National Water Commission (NWC) by using energy efficient pump	MEM/PCJ /NWC	Energy auditors to undertake the audits were pre-qualified and recommendation for contract award was made by the NWC to the National Contracts Commission (NCC).	The NWC accounts for 47% of public sector energy consumption. It is planned to reduce energy cost in this area by installing energy efficient pump motors and power factor

	Project/Initiative	Implementing Agency	Status	Remarks [scenario assignment/comment]
	motors and carrying out power factor correction		Petrocaribe Financing is one of the sources identified. Active participation in negotiations is ongoing through the Petrocaribe Technical Work Team on Savings and Efficient Use of Energy. The proposed project was approved but will be implemented under a regional programme.	correction equipment, as well as explore the opportunity for using solar and wind driven pumps. In this respect, Jamaica hopes to learn from the Cuban experience. *[Scenario 2 in 2 phases – need phase reductions [made assumptions]]* Other sources of finance will help to expand the scope and impact of this programme
35	Energy Education Programme	Ministry of Energy/PCJ	Cuba has indicated that it has a very developed Energy Education Programme which targets all sectors of the Society. Jamaica's efforts at Public Education on Energy Conservation and Efficiency could be enhanced.	A plan will be put in place to ensure development of a cohesive and sustainable public education programme throughout Jamaica. *[Not specifically included]*
36	Waste to Energy Project	PCJ/CERE/NSWMA	Request for Proposal and information on Jamaica's waste were made available to local and international potential investors on January 19, 2009. On April 30, 2009 at the closing date of the process, submissions were received from four (4) international firms, some with local counterparts. Proposals were received for Waste to Electricity, Waste to Ethanol and Gasification of Waste to produce Syngas for sale to the electricity power stations	Evaluation of proposals in progress. Anticipated outcomes include 65MW of electricity from two plants, one in the Eastern and the other in the Western side of the island, or alternately 20 million gallons of fuel based on the proposals received. Avoided importation of 260,000 bbl of crude oil annually *[Scenario 65 MW EFW in all scenarios]*
37	Mini Hydro Development to get 44.7MW and avoid importation of 202,000 Bbls of crude annually	PCJ/CERE	Eight sites identified by PCJ for development within Jamaica. Focus is on the following three: Laughlands Great River – 2MW Back Rio Grande – 25 – 28MW and Great River – 8MW	Other projects to be pursued include the following: Spanish River – 2.6MW Yallahs River – 2.5MW Martha Brae – 4.6MW *[Scenario 2 and Scenario 3]*
38	Bio-Diesel Pilot Project	MEM/PCJ/CERE	In collaboration with tertiary stakeholders, a pilot project is to be undertaken involving	The bio-diesel produced is expected to satisfy ASTM standards and will be tested in

	Project/Initiative	Implementing Agency	Status	Remarks [scenario assignment/comment]
			cultivation of 80-100 acres of marginal lands with bio-diesel feedstock such as castor, jatropha and sun flower	bus engines *[Not applicable to Scenarios]*
39	Use of biomass to generate electricity	PCJ	Project proposal for the use of biomass for the production of up to 200MW of electricity	Memorandum of Understanding signed between PCJ and Biomass Investment Group (BIG) for approximately 30MW of electricity. Need additional info.
40	Dr. Morris Wallen – Wind	PCJ	Wind Farm and Coastal Protection Project for the Palisadoes Strip	*[Could include in Scenario 3 – need proposed MW]*
41	Biogas Assessment Study	PCJ/SRC	Feasibility study to bio-digest all organic waste on the Font Hill Farm and property in St. Elizabeth for Bio-gas production	
42	Barma, America LLC	PCJ	Proposal for 19.5MW wind power generation to JPS through Wigton Wind Farm Ltd.	The project is self financing and presents no financial or other risk to Wigton, PCJ, or Jamaica. Estimated cost is *[Scenario 2]*
43	Energy Knowledge Management	Ministry of Energy	Initial contact was established and preliminary discussion for data definition and specification for system requirement began.	Cuba's Energy Data base Management system provides a system of energy data collection and gathering, information analysis and management for strategic planning of the energy sector is commendable. Information at different levels and for different target groups provides a basis for sound planning and development of the sector. *[Not applicable /relevant for scenarios]*
44	Public Awareness Programmes	PCJ		*[Not specifically included]*
45	Science Competition in Schools	PCJ		
46	Energy Conservation and Efficiency (ECE) and Renewable Energy (RE) in	PCJ		

	Project/Initiative	Implementing Agency	Status	Remarks [scenario assignment/comment]
	Private Sector			
47	Rural Electrification Programme (REP)	REP	Complete construction of 47Km of distribution lines. Complete wiring of 850 houses under GOJ 2006/07 Phase II. Construct 50Km of distribution lines. Complete wiring of 750 houses under Revolving Loan Fund. Continue to pursue Private Projects. Secure funding under the Bandes Agreement for US$9.4M.	*[All scenarios – as penetration of households with electricity]*
48	Rural electrification for rural houses and communities using Renewable Energy (RE) solutions	MEM / REP	Petrocaribe Financing is one of the sources identified. Active participation in negotiations is ongoing through the Petrocaribe Technical Work Group on Renewable Energy. The proposed project was approved but will be implemented under a regional programme. Additional financing will be required to extend this programme.	Cuba's use of RE and alternative energy systems to provide electricity and energy to rural residents and those without easy access to the grid has demonstrated significant reach to thousands of communities. Their innovative strategies to improve the quality of life provide models for replication. *[See above – item 48]*
49	Capacity building for RE technologies and their development	MEM/CERE	Petrocaribe Financing is one of the sources identified. Active participation in negotiations is ongoing through the Petrocaribe Technical Work Group on Renewable Energy. The proposed project was approved but will be implemented under a regional programme.	The knowledge base on RE in Cuba is developing and, while Jamaica has a Centre of Excellence for Renewable Energy (CERE), the human resource and technical facilities and capacity available in Cuba provides for synergies that can be beneficial to Jamaica *[Not applicable /relevant for scenarios]*
50	Manufacturing plant for solar PV modules / panels and solar water heaters	MEM/Ministry of Industry, Investment and Commerce	A proposal for a manufacturing facility for the production of solar PV models and panels and solar water heaters was prepared. Petro-caribe Financing is one of sources identified. Active participation in negotiations is ongoing through the Petrocaribe Technical Work Group on Renewable Energy. The proposed project was approved but will be	A limited capacity exists for the production of PV Modules in Cuba. This capability needs to be strengthened and Jamaica could play a part in order to provide mutual benefits. Both Jamaica and Cuba are located in the same geographic zone that has an abundance of sunshine. The partnership

	Project/Initiative	Implementing Agency	Status	Remarks [scenario assignment/comment]
			implemented under a regional programme. It is further proposed that Jamaica and Cuba develop and use solar energy systems as a solution to supplementing energy needs. Opportunities exist for expanding the product lines to include manufacture and production of other solar powered equipment such as : o Solar Crop dryers o Solar cooling equipment o Other photo voltaic solutions.	would facilitate growth in solar utilization within the region. Cuba has done significant work in this area and the results are quite impressive. Jamaica can benefit from such experience. Collaboration on research and testing of solar devices and equipment, in addition to improving solar equipment efficiencies is another area for bilateral cooperation with Cuba *[Not applicable /relevant for scenarios]*
51	Replacement of incandescent light bulbs with Compact Fluorescent Lamps (CFLs)	MEM/PCJ	The next phase of the distribution of CFLs as part of the gift from Cuba will commence in another few weeks. Dialogue and cooperation with the Cuban Embassy in Jamaica is ongoing and the Cuban government has agreed for the remaining bulbs to be distributed to improve the lighting efficiency within government buildings and facilities. After an audit to determine the requirements per Ministry and their respective agencies is completed, the appropriate control and accounting mechanisms will be adhered to.	Gift of 4 million CFLs from Cuba to help improve savings and efficient use of energy in Jamaica is by far the largest energy conservation and efficiency programme undertaken in Jamaica. The remaining (approximately 365,000) bulbs are to be distributed as replacements for the inefficient bulbs currently in use. *[All scenarios]*
52	Cool Greenhouse Technology	MEM	Cool Greenhouse technology for planting vegetables and other food produce is being developed in Cuba. An opportunity exists for Jamaica to participate and benefit in this new technology. Liaison will continue with the Cuban officials to see how best this partnership can be developed.	The world food crisis and Jamaica's challenge dictate that any partnership in this regard could reap significant benefits for both countries in energy and food security *[Not applicable /relevant for scenarios]*
53	Greenhouse Technology	MEM/Ministry of Agriculture	A proposal for cooperation with Cuba is prepared and as soon as funding is identified and secured, Cuba will be invited to come and	Greenhouse technology is important to Jamaica's food and energy security. *[Not applicable /relevant for scenarios]*

	Project/Initiative	Implementing Agency	Status	Remarks [scenario assignment/comment]
			support Jamaica in the use and further development of this technology	
54	Capacity Building for Carbon Trading	MEM/PCJ	A Task Force was established comprising members from several Ministries and State Agencies to develop a Policy Framework Document.	The capacity for carbon trading must be strengthened so that as Jamaica develops its renewable energy potential and implements effective energy conservation and efficiency programmes, the country's contribution to environmental protection will be demonstrated. *[Not applicable /relevant for scenarios]*
55	Wind Farm Development (Retractable Tower)	MEM/PCJ/CERE	The recent project launch for the expansion of the Wigton wind farm generation plant is a reminder that Jamaica has the capacity and will to develop its renewable energy sources. When completed, this will result in the increase capacity of the farm by 18.0MW. Petrocaribe Financing is one of the sources identified. Active participation in negotiations is ongoing through the Petrocaribe Technical Work Group on Renewable Energy. The proposed project was approved but will be implemented under a regional programme.	Cuba is seriously expanding its wind energy contribution to electricity production. Their use of Retractable arm wind turbines is a safeguard against damage by hurricane force winds. Jamaica needs this technology for future wind energy development *[Not applicable /relevant for scenarios]*
56	Determination of Jamaica's wind energy potential	MEM/Energy/PCJ/CERE/Wigton Wind Farm Ltd.	An MOU has been signed between PCJ and UWI for partnership in updating Jamaica's wind energy potential. As soon as funding is identified and secured a consultant will be engaged to conduct the study of Jamaica's wind potential in order to determine the current potential for development. Petrocaribe Financing and IDB's Sustainable Energy and Climate Change Initiative (SECCI) are two of the sources of finance identified.	Active participation in negotiations is ongoing through the Petrocaribe Technical Work Group on Renewable Energy. The proposed project was approved but will be implemented under a regional programme. Also, an application for financial support was made to SECCI for their consideration. The last study conducted will be updated and made available for investment opportunities.

	Project/Initiative	Implementing Agency	Status	Remarks [scenario assignment/comment]
				[Not applicable /relevant for scenarios]
57	Hydro and Waste To Energy development	MEM/OUR	Proposal for development of up to 80MW of hydro power electricity plant and 10Mw of Waste to Energy power plant by investor Global Green Energy Services (GGES)	Investor will do entire development without any guarantee from the GOJ or any payment required until electricity is sent to the national electric grid. *[Not applicable /relevant for scenarios]*
58	Solar Radiation and Intensity Mapping	MEM	Initial discussions started with Cuba and will continue. Financial support will be provided under the Petrocaribe initiative through the Technical Work Group on renewable energy.	Cuba's achievement in this area provides a basis for further collaboration. *[Not applicable /relevant for scenarios]*
59	Wigton Wind Farm Reactive Power (MVARS) Improvement	MEM/PCJ/CERE	Petrocaribe Financing is one of the sources identified. Active participation in negotiations is ongoing through the Petrocaribe Technical Work Group on Renewable Energy. The proposed project was approved but will be implemented under a regional programme.	Successful implementation of this project will significantly improve the efficiency, availability and profitability of the state owned wind farm. *[Scenario 2]*
60	Wigton Wind Farm Expansion	MEM/PCJ/WWFL	Expansion of wind farm by 18MW	Power purchase Agreement (PPA) with JPS to be negotiated for the expanded Wind Farm *[Scenarios 2 & 3]* Negotiate Carbon Trading Arrangements for expanded facility to be done *[Not applicable /relevant for scenarios]*
61	Carbon Trading Framework	PCJ/CERE/WWFL	Development of a framework for future wind projects	*[Not applicable /relevant for scenarios]*
62	Demonstration project for a 2.0MW gearless box wind turbine (turbine without gear box)	Ministry of Energy/PCJ/CERE	Petrocaribe Financing is one of the sources identified. Active participation in negotiations is ongoing through the Petrocaribe Technical Work Group on Renewable Energy. The proposed project was approved but will be implemented under a regional programme.	This new technological application in Jamaica will increase the options for wind energy development. *[Not applicable /relevant for scenarios]*
63	Market Driven Initiative to			*[Not applicable /relevant for scenarios]*

	Project/Initiative	Implementing Agency	Status	Remarks [scenario assignment/comment]
	Encourage Greater Use of Renewable Energy and Energy Efficiency Technologies			
64	Solar PV Systems to supply electricity for schools	MEM/PCJ	A project to supply electricity to schools has been developed. Petrocaribe Financing is one of the sources identified. Active participation in negotiations is ongoing through the Petrocaribe Technical Work Group on Renewable Energy. The proposed project was approved but will be implemented under a regional programme.	The proposed PV system will be grid – tied without energy storage solutions therefore is dependent on the development of Net Metering Policy and legislation to support implementation *[Need additional data – include in Government sub-branch?]*
	ENERGY DATA BASE AND PLANNING			
65	Planning and Data Base Management for Sustainable Development	OPM/EMD		*[Not applicable /relevant to scenarios]*
66	Energy Database Management System	MEM	International Atomic Energy Agency (IAEA) Module for Assessment of Energy Demand - MAED	*[Not applicable /relevant to scenarios]*
67	Vision 2030 Jamaica National Development Plan	PIOJ	PIOJ led a Task Force to develop Vision 2030 Development Framework for Jamaica	Final report circulated *[Not applicable to scenarios]*
68	Carbon Emissions Database (Software) for monitoring and managing energy consumption data in ministries and agencies (LPG, electricity, gasoline and diesel oil)	OPM/EMD		*[Not applicable to scenarios]*
69	Public Education Initiatives on Energy	NEPA		
70	Energy Conservation Officers	MEM/Cabinet Office	Assignment of Energy Conservation Officers in each Ministry, Agency and Department to monitor and control public sector energy	Reduce public sector consumption by 15% *[Scenarios 2, 3]*

	Project/Initiative	Implementing Agency	Status	Remarks [scenario assignment/comment]
			consumption	
71	Training in Energy Management	MEM/Cabinet Office		*[Not applicable /relevant to scenarios]*
72	Second National Communication to the UNFCCC Project	OPM/EMD/ Meteorological Office		*[Not applicable /relevant to scenarios]*
73	Jamaica Productivity Centre – Monitoring of Energy Use	Ministry of Finance and the Public Service		*[Not applicable to scenarios]*
74	Energy and Power Evaluation Programme (ENPEP)	MEM		*[Not applicable to scenarios]*
75	National Energy Coordinators Committee	MEM		*[Not applicable to scenarios]*
76	End-Use Survey for Commercial and Public Sectors	MEM/STATIN/PIOJ		*[Not applicable to scenarios]*
77	GOJ Energy Management Guidelines	OPM/EMD		*[Not applicable to scenarios]*
78	Renewable Energy Development	PCJ/CERE	Research on renewable energies, assessment, design and implementation of RE projects	*[Not applicable to scenarios]*
79	Inner City Schools Energy Conservation Programme	PCJ	Adapting conservation and energy efficiency for local use, involved in project on energy saving bulbs, public sector energy systems upgrade, energy conservation incentive programmes for inner-city schools	*[Not applicable to scenarios]*
	OTHER			
80	JMA Energy Conservation Programme	MIIC/JMA	Enhancing the Competitive Advantage of the Manufacturing Sector through Energy Conservation (Paper)	[No data available]
81	Chicago Based Project			[No data available]
82	Virginia Based Project			[No data available]
83	Ethanol project		Ethanol Plant Development	Colombian Embassy [No data available]

[i] Petrojam (March 2000). Personal communication from W. Henry, Petrojam Ltd.

[ii] *PIOJ, STATIN, (2007). Residential Consumer End Use Survey: Volume 1 - Household Energy & Transport, Draft Report Prepared for: The Petroleum Corporation of Jamaica*

[iii] STATIN, PIOJ (2007). Residential Consumer End Use Survey: Volume 1 – Household Energy and Transport. Draft Report prepared by STATIN and PIOJ for the Petroleum Corporation of Jamaica, January 2007.

[iv] Sugar Industry Authority web site http://www.jamaicasugar.org/SIAIndex.htm.

[v] UNFCC Web Site http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php

http://unfccc.int/resource/docs/natc/jamnc1.pdf

CHAPTER 4: ....PROGRAMMES CONTAINING MEASURES TO FACILITATE ADEQUATE ADAPTATION TO CLIMATE CHANGE

Climate change impacts for the years 2015, 2030, and 2050, were considered as part of the vulnerability and adaptation (V&A) assessments undertaken for five priority sectors: agriculture, water resources, human health, coastal zones and human settlements, and tourism.

Methodological Approach

The UNDP Adaptation Policy Framework methodology provided the overarching approach for the V&A assessments, coupled with the most appropriate existing analytical tools. Maximising stakeholder engagement was a high priority for the sectoral assessments, to the extent possible under the timeframe and funding circumstances. This included various workshops throughout the process to invite technical inputs on the V&A assessments and the resulting policies and measures recommended.

Future climate scenarios were developed using those presented in the IPCC Special Report on Emission Scenarios (IPCC, 2000), which are driven by demographic changes, GDP growth, energy and technology change, as well as land use change. Climate modelling results were produced by the UWI Climate Modelling Group across the A1B, A2, B1 and B2 scenarios of the IPCC using three different general circulations models (GCM) (HAD, MRI, ECH), one regional climate model (RCM) (PRECIS), as well as statistical downscaling at two locations using the Statistical DownScaling Model (SDSM) developed by Wilby *et al* (2002) (Table 4.1).

Table 4.1: Summary of Climate Modelling Applications

Modelling Approach	Model Name	Scenarios			
		A1B	A2	B1	B2
AOGCM	HAD	✓	✓	✓	
	MRI	✓	✓	✓	
	ECH	✓	✓	✓	
RCM	PRECIS		✓		✓
Statistical Downscaling	Mo'Bay + Worthy Park		✓		✓

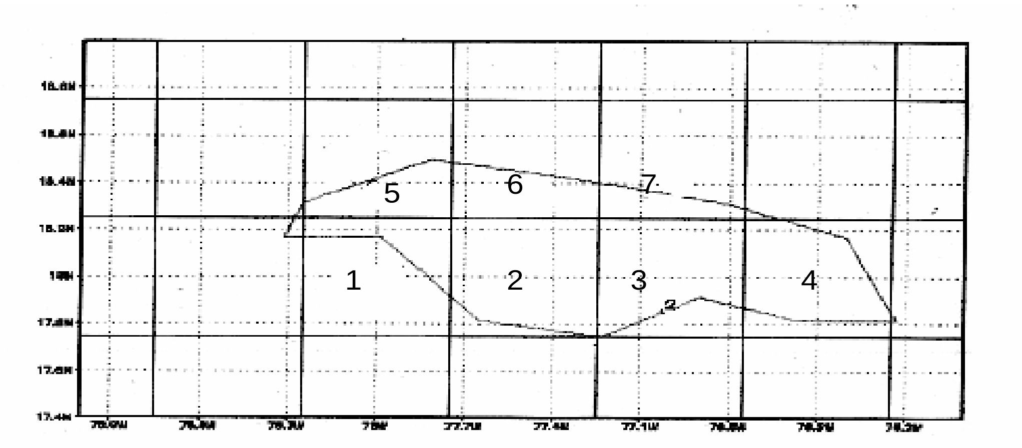
Analysis of the results produced by each of these approaches showed some consistency, but also both model and scenario variations across the same scenarios and models respectively, when looking forward at 2015, 2030, 2050 and 2080. Given these results, it was decided that in assessing the potential impacts of climate change on the water resources and agriculture sectors, the results from the GCM modelling would be taken forward as a pooled set of estimates

For the tourism sector, a model was created based primarily on population components, with the following assumptions:

- Population size, growth, quality and capabilities are major variables that dictate the cost, progress and overall performance of the socio-economy and attitudes towards environment.
- Political lobby forces are dictated by population attitudes in most modern societies. This is a high symptom of democratization.

The PRECIS model, with a resolution of 50km x 50km, was used to generate projections for seven regions of Jamaica (Figure 4.1).

Figure 4.1: The seven regions of Jamaica defined using the PRECIS regional climate model



4.1 Existing & Future Climate in the Caribbean and Jamaica

The annual average rainfall in Jamaica is 1,871 mm based on data from the National Meteorological Service for 1981 to 2007. While there are no discernable long-term trends in annual rainfall totals, the maximum level of consecutive dry days is increasing and the number of heavy rain days is increasing. While there are variations in tropical and extra-tropical cyclone activities, such as hurricanes and typhoons, daily temperatures are at an average of 26.2° Celsius to 30.0° Celsius over coastal areas. According to the 2007 IPCC 4^{th} Assessment Report, warming within the Caribbean ranged from 0.0° Celsius to 0.5° Celsius per decade from 1971 to 2004.

The best estimates for temperature and precipitation changes are summarised in Table 4.2. They are based on averages of A2 and B2 SRES scenarios.[28] The regions referred to are those generated by the PRECIS model (Figure 4.1). There is an indication of consistent temperature warming across all seasons and scenarios. The projected 1.5°to 2.8 Celsius increase in temperature by 2050 and 2080 respectively will result in increased evaporation losses, decreased precipitation, and a continuation of rainfall decline. Also shown are percentage changes in wet-days, wet-spell lengths and dry spell-lengths for two regions. In general, temperatures will increase and rainfall, wet-days and wet-spells will decrease, while dry-spells will increase.[29]

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[28] These scenarios are described in Chen (2008). The average is basically an intermediate scenario between an economy driven by growth in wealth and an economy which considers environmental stability on one hand, and an intermediate scenario between an economy based on globalization and an economy based on regionalization on the other hand.

[29] Wet-days, wet-spells and dry-spells are precisely defined in Chen (2008).

Table 4.2: Best Estimates of Absolute Temperature Change and Percentage Change in Rainfall for Jamaica (2050s, 2080s)

Parameters	2050s	2080s
Temperature (degree Celsius)	1.5	2.8
Precipitation (% change)		
Region 1	0	-30
Region 2	-10	-30
Region 3	-10	-20
Region 4: Portland	No estimate	-40
Region 4: St. Thomas	No estimate	-20
Region 5	-10	-40
Region 6	-10	-30
Region 7	-10	-30
Region 5		
Wet-day(s) %	-24	-44
Wet-spell length	-7	-10
Dry-spell length	32	80
Region 3		
Wet-day(s) %	-2	-7
Wet-spell length	-3	-6
Dry-spell length	1	4

Estimates of sea level rise and evapotranspiration were obtained from observations and GCM results reported by IPCC Working Group1 for IPCC Fourth Assessment Report (Meehl, 2007). By the end of the century, sea levels are also expected to rise by 0.21m to 0.48m under an A1B scenario, but the models exclude future rapid dynamical changes in ice flow. One study suggests that the rate of rise may actually double (Science Daily, Feb. 12, 2008). Evaporation is also projected to increase by approximately 0.3mm/day over the sea. As noted before, the changes over land may be less.

Projections for hurricanes were based on a single GCM running at high resolution with a 20 km mesh (Oochie et al., 2006). One model has projected more intense hurricanes in the Atlantic.

Uncertainties

The climate outcomes outlined above are by no means certain. They should be viewed on a scale of probabilities and on the projected emission scenarios. The vulnerabilities described will largely depend on social conditions and the ability of the government to finance adaptation measures.

Based on the A1B scenario described above and on expert judgment, the probability that temperatures will increase and precipitation decrease are greater than 90 percent. However the magnitudes of the changes are less uncertain. The probability of a range of temperature increase between 2ºC and -2.8ºC by the 2050s and 2080s respectively is greater than 66 percent, but the magnitude of the precipitation decreases is less certain. This is because while the science of global warming is well understood and the processes leading to it can be well simulated, the confidence associated with modelling of precipitation is not as high.

The probability of sea level rising over the next century is greater than 66 percent, but the magnitude of the rise is uncertain because of the large deviation among sea level rise models, and the absence of regional models. The possibility of increased storms is unclear.

A joint statement by participants of the WMO International Workshop on Tropical Cyclones, IWTC-6, in San Jose, Costa Rica, November 2006, states that, "Given the consistency between high resolution global models, regional hurricane models and MPI (Maximum Potential Intensity) theories, it is likely that some increase in tropical cyclone intensity will occur if the climate continues to warm". A more recent paper by Knutson et al., (2008) does not support the notion of large increasing trends in either tropical storm or hurricane frequency driven by increases in atmospheric greenhouse-gas concentrations. At the same time, the paper does not contradict the idea that near-storm rainfall rates will increase substantially, and that cyclone intensity will increase.

4.2 The Agriculture Sector

4.2.1 Main Characteristics of the Agriculture Sector in Jamaica

Jamaican agriculture is characterised by either large scale plantation production or much smaller scale mixed cropping. The large-scale production includes crops such as sugarcane, bananas, and coffee for the export market. This production had its origins in the period of colonial expansion in the eighteenth and nineteenth centuries when the economy was based on plantation agriculture and slave labour. In contrast, the small-scale farming, which accounts for the greater proportion of farm labour, produces a wide range of crops mainly for the domestic market. The crops include yam, potato, dasheen, coco, banana, plantain, cassava, peas, beans, pumpkin, and a wide range of tropical fruit and vegetables. The small-scale farms emerged significantly after the slaves were freed, withdrew from the estates, and began planting their own plots.

The evolution of agriculture in Jamaica and the Eastern Caribbean is typical of many other tropical developing countries but quite different from older economies. In older economies, agriculture developed on the basis of subsistence and self-sufficiency within the farm. This was before the cash economy and the spread of industrialisation. Animals and crops were produced for household consumption and not for sale. Centralised marketing was established and self-sufficiency on the farm was gradually superseded by a cash economy as communication improved. The early subsistence economy gradually changed and the production of cash crops increased. Trade began in towns nearby then later expanded to more distant buyers.

The origin of Jamaican agriculture was based on crops produced for the international market on plantations financed by external capital and a slave labour system. The mono cropping of export crops generated vulnerable, open economies dependent on food imports, which further deterred the development of small-farm food production. Unlike more developed economies, the role of Jamaican agriculture was not to provide food for its local population but for export. The economy in turn, relied on foreign exchange earned from the export of crops to import staple food. The import of staple food is still a major trend of the Jamaican economy.

Jamaica imported far more agricultural commodities than it exported during the 1970s and 1980s. However, the economy is now recording an agricultural trade surplus. In 1994, the value of food imports was US$136.1 million while agricultural exports totalled US$ 167.3 million, yielding a surplus of US$ 31.2 million (Planning Institute of Jamaica, 1994).

The agricultural sector has seen a decrease in natural agricultural resources. The 1982 Provisional Farmers Register of the Jamaican Ministry of Agriculture recorded a total of 369,138 hectares (922, 845.9 acres) of total farm acreage in Jamaica. The total land area occupied by farms in 1978 was 537, 453 hectares, which is 10.9 percent less than that recorded by the previous census in 1968 of 603,126 hectares. Thirty percent of the land has slopes ranging from 2 degrees to 20 degrees, and 50 percent has slopes of over 20 degrees (IICA, 1994).

Jamaica is particularly susceptible to watershed degradation, as approximately 80 percent of the land surface is hilly or mountainous, with more than 50 percent having slopes of greater than 20 degrees. The two generalised sectors of Jamaican agriculture show distinctive topographical features. Large-scale farmers that practice mono-cropping of export crops occupy the most resource-rich lands – that is, the coastal plains and the interior valleys with relatively fertile soils. Small farming occupies the upland of the central parishes and the hilly areas of the remaining parishes. It is noticeable that the smaller the farm, the higher the proportion of mixed cropping and the higher the proportion of food crops for domestic consumption rather than crops for export. Pastures and grassland used for animal feed are located predominantly in the north-central and western parishes of Jamaica.

Soils in small farming areas are moderately fertile and have been badly eroded. A high rate of removal of natural vegetation of 3.3 percent annually from the island's watersheds has continued over the last 30 years. Four hundred million tonnes of soil were lost from the island over the last 10 years (IICA, 1994). The Natural Resources Conservation Department (NRCD, 1984), which is now the National Environment & Planning Agency (NEPA), has reported that 16 percent of the island's land area is seriously eroded and that loss of topsoil averages 40 to 50 tons annually. Each of Jamaica's 26 watershed management units has portions which are considered to be badly eroded (Jamaica State of the Environment Report, 1997). Farming activities such as unregulated burning and cutting forestry for logs, yam sticks, fuel-wood and charcoal burning, coupled with poor agronomic techniques, all contribute to the degradation of watershed areas.

The distinctive spatial inequality that exists in the distribution of good agricultural land between the two farming sectors is one of the features of Jamaican agriculture that remain deeply ingrained. Land concentration remains among a small number of large farms, while good agricultural land is a scarce commodity among thousands of small farmers. The Jamaican land reform programmes of the 1960s and 1970s did not succeed in creating any true structural changes in the distribution of agricultural land. Neither has the small farmers benefited from the recent reduction in the acreage under sugarcane.

Besides the inequality in the size of land and terrain, small operators are further disadvantaged in that their farms are usually made up of two, three, or even four separate fragments of land at considerable distances apart. Some scholars have assessed this phenomenon as a major spatial barrier to agricultural advancement. Fragmentation affects time spent on scattered plots, land use variations, and time is wasted travelling to distant plots. The majority of large farms are contiguous holdings.

The unequal distribution of land resources has important implications for the distribution of income, the economic well being of farmers and, environmental management, and threatens aspirations for sustainable agriculture.

Land Tenure

As noted above, the present land tenure system is an outcome of the pattern of settlement during the colonial era. The most fertile lands on the plains and coastal areas were allocated to the first settlers, who cultivated sugar cane and other crops under a plantation system based on slavery. After the abolition of slavery the only land available to freed slaves was in the hilly interior. These Crown lands, were owned by the government, thus the first occupants could only establish usufruct rights. Subsequently, government regularised this tenure and granted titles to the land through various programmes. Progress has been slow, and most of this land is still untitled. Land in the coastal areas continues to be a part of large estates, although the government has acquired several of them.

Privately owned land, family-owned land (belonging to a descent group that can normally be used by all members), rented land, leasehold, squatted land, caretaking, and rent-free represent the tenurial arrangements among farmers in Jamaica. Privately owned land and leasehold are the two common options among the large plantations. The small farming sector has a greater mix of tenurial arrangements. Some small farmers may have a different tenurial arrangement for each piece of land.

Around 80 percent of all agricultural land is owned. However, among those farming less than two hectares (this group represents over 80 percent of farmers); only 50 to 60 percent of the land is owned. After ownership, leased land is the second most important tenure, accounting for 9 percent of the land area, followed by rent free (5%), rented (4%), and squatting (4%). However, the distribution varies with farm size. Thirteen percent of farms of less than 0.4 hectares of land are rented and 21 percent of the land is rent free. For farms between 0.4 and 2 hectares category, 14 percent of the land is leased, 12 percent is held rent-free and 11 percent is rented. The proportion of land owned increases with farm size, the largest operators owning over 90 percent of the land they farm. Thus, insecure forms of tenure are more closely associated with smaller farmers, and with poverty.

Size of Farms

The size of farms is an important variable as it indicates expansion and development potential of production units. The concept of size as used here is defined on the basis of total land area. The Jamaican Ministry of Agriculture defines small farms as those between 0.1 to 25 acres. As noted above, land distribution is highly concentrated in Jamaica. Official national statistics show the extremely skewed distribution of farm sizes (Table 4.3).

Table 4.3: Farm Size Distribution and Number of Farmers in 2007

Size Group of Farms	Area occupied (ha)	% Total	Number of Farmers	% Total
0	0	0	28,070 (landless)	12.3
< 1ha	47,712	15%	151,929	66.4
1 to <5ha	86,011	26%	43,731	19.1
5 to <50ha	50,783	16%	4,543	2.0
50 to <200ha	25,449	8%	270	0.1
>200ha	115,854	36%	140	0.1
Total	**325,809**	**100%**	**22,638**	**100**

Source: STATIN, Census of Agriculture 2007

The unbalanced pattern of land distribution is a major explanation for the marked uneven distribution of rural incomes, particularly in the context of the small share of total income accruing to the small-scale farming in relation to the number of people it supports. As demonstrated in Table 4.3, farms between 0 to 5 hectares covered 41% of agriculturally productive land in 2007, cultivated by 85.5% of farmers. In sharp contrast, farms of equal to or greater than 200hectares accounted for 42% of agriculturally productive land but were cultivated by less that 0.2 of farmers.

The use of land area as a measurement of farm size does not take into consideration land quality and the intensity of use. Paradoxically, there are large proportions of unused lands on small farms and to a lesser extent on large farms, estimated at 10 percent of cultivable land (Blustain, 1981). Recent empirical studies in several small farming communities in Jamaica reveal a figure of between 45 and 50 percent of total farm acreage lying unused (Meikle, 1993 and 1994).

Farmland in small farming communities is under-utilised or unused because rates of capital formation are generally low. Low incomes limit the capacity to save, which in turn limit the farmers' ability to re-invest. Old age or ill health of some farmers also limits production and, to a lesser extent, steep slopes and long distances from the roadside. Lack of capital is overall the main factor limiting the optimal exploitation of land resources among the small farmers.

Idle lands suggest that the use of land is not intensive as is common in some developing countries. It also indicates that the need for expansion into new areas is perhaps not as great in Jamaica. The factors accounting for idle and under-utilisation of agricultural land should be a matter of priority investigation and be taken into account in developmental activities especially in light of: (a) increased emphasis on the production of non-traditional export crops on small farms in a liberalised economy, and (b) continued use of environmentally fragile areas.

Agricultural Credit

During 2006, the Government of Jamaica continued to make loans available for potentially viable agricultural projects through a range of financial intermediaries. The uptake of loan funds from the Development Bank of Jamaica via the People’s Co-operative Bank and other approved Financial Institutions amounted to J$37.3 million compared with J$505.1 million in 2005.

The most significant decline in loan utilisation was recorded for livestock which moved to J$68.3 million from J$335.4 million in 2005. Loans for livestock production in 2005 were pushed mainly by the poultry industry which accounted for 95.1 % of loans. These loans were mainly used for retooling activities. Declines in loan utilisation were also recorded for Domestic Crops and Export Crops, which fell by J$6.4 million and J$4.5 million respectively.

Farmers are allowed to access local currency loans at a rate of 13.0 % per annum. The wholesale lending rate from the Development Bank of Jamaica to Approved Financial Institutions was 10.0 %. There were no foreign currency loans to the Agricultural Sector in 2006.

Loan allocations to the main sub-sectors of the Agricultural Sector for the period 2002-2006 inclusive are presented in Table 4.4.

Table 4.4: Loan Allocation to the Agricultural Sector 2002-2006

(J$ '000)

Sector	2002	2003	2004	2005	2006	Totals
Domestic Crops	6,383	11,794	2,301	10,098	3,660	34,236
Export Crops	177,935	42,039	91,658	8,630	4,140	324,402
Livestock	128,767	176,494	57,024	335,386	68,276	765,947
Farm Infrastructure	11,032	0	68,000	0	1,260	80,292
Agro-processing	121,229	90,500	364,923	151,000	294,000	1,021,652
Totals	445,334	320,826	583,905	505,114	371,336	2,226,515

Source: Planning Institute of Jamaica (2006)

The degree of access to farm credit is directly related to farm size with larger farmers having greater access to credit than small farmers. The disparity in the amount of credit allocated to the domestic versus the export sectors is illustrated in Table 4.4, and extends back into the 1990s, although in 2005 and 2006, the allocations for both sectors were similar and historically low.

Access to loans for investment by farmers in the domestic sector is important to allow them to move into growing either new varieties of existing traditional crops or new crops, and thereby increase their capacity to respond positively to changing markets or environmental conditions including climate change.

Agricultural Technology

The use of farm equipment, irrigation, and agro-chemicals varies directly with the size of farm. Farms of less than 2.3 hectares (5 acres) access only 8 percent of farm machinery and over 70 percent of the manual equipment whereas, farms of over 227.3 hectares (500 acres) access 62 percent of mechanical energy powered heavy agricultural equipment and 2 percent of manually operated tools.

The small farm sector continues to be labour intensive. Many agricultural projects aimed at small farmers encourage farmers to change their agronomic practices either by changing their crops, intensifying their production, or increasing agro-chemical use. Assessments of sustainability of agricultural technologies are rarely worked out and this sometimes leads to unfavourable repercussions both on the environment and on the quality and quantity of produce.

4.2.2 Institutional Arrangements for the Management of Agriculture in Jamaica

The **Ministry of Agriculture and Fisheries** is the prime arm of the Government of Jamaica responsible for the management and development of Jamaican agriculture. It implements these responsibilities through a number of Directorates and Divisions, including:

- *Technical Services Directorate*: responsible for directing and coordinating research and development, veterinary services, fisheries, public gardens, plant quarantine, and the forestry department;

- *Policy Coordination and Administration Directorate:* establishes a framework of policy coordination, monitoring, evaluation, and information exchange between internal and external clients;
- *Agricultural Planning, Policy and Development Division:* Provides information on a continuing basis to assist the Ministry in formulating agricultural policies within the ambit of national development and plays a leading role in all aspects of agricultural development planning. Also directs and supervises the work of the Economic Planning, Data Bank & Evaluation, Agricultural Credit and Marketing, and International Trade Units;
- *Data Bank & Evaluation Division:* Responsible for providing the Ministry's agricultural commodity associations, other agricultural and allied bodies, farmers, and international agencies with agricultural data and information;
- *Marketing and Credit Services Division:* Provides the relevant regulatory and support system to facilitate the marketing of agricultural food products and consequently introduce improvement in the marketing system;
- *Land Policy and Administration Directorate:* Analyzes and refines the National Land Policy and creates linkages with environmental agencies, promoting and maintaining environmental sustainability and harmony with competing forms of land use. Also coordinates and oversees the work of the Land Administration and Management, Minerals Policy and Development, Spatial Data Management, and Rural Physical Planning divisions, particularly with respect to the:
    - development, implementation, and monitoring of portfolio policies, programmes, projects, legislative, regulatory and policy instruments, and related activities;
    - revision, modernization, and introduction of relevant legislation and policies;
    - guiding of work on the planned systematic development of the minerals industry;
    - facilitation of sustainability requirements of the non-bauxite minerals sector;
    - coordination with agencies such as the Mines and Geology Division, National Land Agency and the Forestry Department in achieving sustainable land development;
    - direction and guidance on all land related agencies and projects of the Ministry;
    - evolution of the work of the Spatial Data Management Division to promote and facilitate the use of GIS and geo-spatial data in all spheres of government activity;
    - creation of synergies and linkages amongst the various Ministerial divisions and their technical responsibilities.

There are a number of **Commodity Boards** that have a significant role in the development of agriculture in Jamaica. These include:

- *Banana Board:* Statutory body established under the Banana Board Act of 1953 with responsibility to: inform government on status of the industry and any necessary actions; promote and develop the interest and efficiency of the banana industry; to institute, conduct, finance, assist, and superintend research for improving production, controlling disease, and developing disease-resistant fruit; and administer the Banana Insurance Fund.

- *Cocoa Industry Board*: Statutory body established and operated under the Cocoa Industry Board Act of 1957. Through the Board, Jamaica is a member of the International Cocoa Organisation (ICCO) and a signatory to the agreement. The ICCO recognizes 17 countries as producers of fine or flavoured cocoa; Jamaica is recognized as one of eight exclusive producers. The core function of the Board is the international marketing. (A significant portion of the beans is exported primarily to Europe, Japan, and the United States; only a small quantity is sold domestically.)

- *Coconut Industry Board:* Established under the Coconut Industry Control Act in 1945. The Board promotes the interest and efficiency of the coconut industry, encourages the production of coconuts, and regulates the purchase, sale, and exportation of coconut, as well as the importation of coconut products and substitutes. The Board also informs and advises the government on the industry and needed actions, issues licences to manufacturers of coconut product, arranges crop insurance; assists growers to market their crops, and carries out research on the agricultural problems of the industry.

- *Coffee Industry Board*: Established under the Coffee Industry Regulations Act of 1948. The principal role is to promote, regulate, monitor and guide the development of the coffee industry of Jamaica and to assure quality of Jamaican coffee mainly through licensing and monitoring of coffee dealers, processors, works and nurseries (the board owns the Jamaica Blue Mountain® and Jamaican High Mountain Supreme® coffee trademarks and is responsible for the integrity of the brands); certification of quality standards, growing areas, and plant varieties; and advisory services, such as monitoring and forecasting of crop condition, technical advice to farmer groups on planting, pre- and post-harvesting techniques, pest and disease control and environmental management.

- *Dairy Development Board*: Established following Cabinet Resolution of July 1999. The Board's mandate is to ensure a policy environment which will promote the orderly development of the Jamaican Dairy Industry by: collecting, compiling and analyzing data on the local and international dairy markets to provide the basis for appropriate policy intervention; consulting with stakeholders of the dairy sector toward the formulation appropriate of public policy; initiating on-farm and in-plant assessments to determine efficiencies and identify and recommend solutions to production deficiencies; assisting in identifying and procuring financial and technical support for enhancing competitiveness within the sector; and conducting training workshops and seminars for sector stakeholders.

- *Export Division (Pimento):* The Export Division of the Ministry of Agriculture is responsible for collecting, storing, processing, marketing and shipping of pimento, together with the overall development of the industry. The pimento industry consistently earns over US$5 million annually, from pimento berry, pimento leaf oil, pimento berry oil and other products. In order to encourage increased production, government has increased the Farmgate price of pimento by 161%, moving the price from $50.71 to $132.28 per kilo ($23.00 to $60.00 per lb) over the last five-year period. Since 1999, the Export Division has also been assisting ginger growers in the re-development of that industry which was devastated by Rhizome Rot Disease. It currently guarantees markets for fresh/green, dried and peeled traditional type Jamaican ginger and nutmeg.

- *Sugar Industry Authority*: The Sugar main functions are regulatory, monitoring, arbitration, research and development the provision of and technical assistance, with greater emphasis being placed on research to enhance production and productivity. The organization also advises on industry developments, trends and prices.

The **Forestry Department** is mandated to conserve and protect the island's forests, to manage the forested watersheds and forestlands, to direct and control the exploitation of forest resources through the introduction of appropriate systems for the renewal of those resources, the promotion and regulation of forest industries, forest research, public education and forestry training and education. The Government has revised legislation to reflect these policies and has also strengthened and upgraded the Forest Department to an autonomous body, thus enabling it to develop a Forest Management and Conservation Plan. The Government has received assistance from the Canadian International Development Agency (CIDA) to establish Trees for the Tomorrow project which has assisted the department in developing the institutional framework and the capability to undertake long-term planning of forests and improved watershed management.

The objectives of the Department are to:

1. Develop and maintain recreational sites at suitable locations in the forest reserves to provide forest recreation in the form of camping, hiking and general appreciation for the forest environment.
2. Ensure annual incremental increases in forest cover within the upper and middle watersheds.
3. Regulate the orderly development of the forest estate.
4. Improve the planning and management of the Forestry Department and National Environmental Societies Trust members and other government institutions to manage the project cycle.
5. Strengthen the institutional capabilities in the Jamaican forest sector, top plan and implement sustainable forest management, and increase awareness of forest throughout the country.

The **National Land Agency** was established as the result of the Public Sector Modernisation Programme undertaken by the Government of Jamaica. It brings together the core land information functions of Government under one roof, and includes: Land Titles; Surveys & Mapping; Land Valuation & Estate (Crown Land) Management. This merger enables the Government to build on the synergy of these combined functions and create a modern national land (spatial) information system to support sustainable development.

There are also a range of **statutory bodies** that have a role in the development of Jamaican agriculture. These include:

- *Agri-Business Council of Jamaica:* Launched in 1994 to coordinate the efforts of private and public agri-business interests throughout Jamaica so as to positively impact on the development of Jamaica’s agri-business sector. ABC fulfils its mandate through providing effective linkages between agricultural producers/service providers and the Ministry of Agriculture and Lands as well as other relevant agencies.

- *Agricultural Development Corporation*: This body aims to activate, stimulate, facilitate and undertake agricultural development for enhancement of the economic wellbeing of the Jamaican people. Its main strategic objective is to ensuring there is an organizational structure to adequately implement commercialization of agriculture. One key output is to enhance improvement in the quality of livestock in the cattle industry as a whole and to preserve and expand the gene pool of the three Jamaican beef cattle breeds.

- *Jamaican Agricultural Society*: The Society promotes farmers' interests, provides technical training on sustainable production, and assistance in accessing resources. Its vision is to reconstruct rural communities throughout Jamaica into viable economic and social entities.

- *Jamaica 4H Clubs*: The aims of the clubs are to mobilize, educate, and train young people between the ages of nine to 25 years in agriculture, homemaking, leadership, and social skills, which will prepare them for or influence them into careers in agriculture and agro-related occupations, and provide a cadre of trained young leaders, capable of contributing to national development.

- *Rural Agricultural Development Authority*: Promotes agricultural production as the main engine of growth in rural communities and helps provide technical, marketing, financial, and infrastructural facilities and the social services required for the improvement of the quality of life of farm families. The broad objectives include:
    - Providing a technical advisory extension service aimed at encouraging and promoting agricultural practices that will facilitate self-sustaining growth and development within the farming community;
    - Influencing policy action that speaks to rural development;
    - Increasing production and productivity, thereby enhancing growth and development within the agricultural sector;
    - Stemming environmental degradation in general and in critical watershed areas in particular and pursuing development strategies aimed at achieving long term conservation objectives and promoting efficient use of natural resources;
    - Exposing rural women to skill training opportunities in agro-processing and the culinary arts and business management with a view to preparing them either for employment or to operate their own business;
    - Develop an integrated approach to rural development through the fostering of operational linkages with other organizations concerned with rural development.

Agricultural Development Strategy (2005-08)

The Agricultural Development Strategy (2005-08) was developed by the Ministry of Agricultural as part of a long term plan to transform Jamaican agriculture by 2020 (Government of Jamaica, 2005). It is seeking to develop agriculture's contribution to Jamaica's renewed medium-term economic growth and to secure sustainable development in the long term. Agriculture, due to its impact on food security and the cost of living; the existence of good opportunities for exports; and the contribution to employment and rural development has the special potential for contributing to short-term stability, medium term growth and long term development.

The revitalization of the agricultural sector and its increased contribution to the national economy will depend, however, on the re-organisation of the sector on the basis of modern technology and management, in order to achieve greater efficiency and competitiveness. The strategy has five major themes, which will be applied to major programmes and practices. These are: (1) Competitive Agriculture; (2) Efficient Commercial Farming; (3) Application of Technology; (4) Integrated Rural Development; and (5) Involvement of Young People. Financing of the projects and programmes to support implementation of the strategy comes from the Government of Jamaica, external sources and the local Private Sector/NGOs.

4.2.3 The Role of Agriculture in the Jamaican Economy

Agriculture remains central to the Jamaican economy for employment and foreign exchange generation despite the decline in number of persons involved. The 1943 Jamaican census of population showed that 45 percent of the working population earned their living from agriculture. The proportion of the labour force in agriculture has decreased since then to 24.4 percent in 1994, down to17.9 percent in 2006. The government's recurrent and capital expenditure on agriculture in 1975 was 14.8 percent. By 1990, this fell to 2.0 percent and was down to 1.5 percent in 2006. Agriculture contributed 28 percent to GDP in 1943, 8 percent in 1994 and 5.5 percent in 2006 (Planning Institute of Jamaica, 1991, 1994, 2007).

The Planning Institute of Jamaica measures agricultural production using an Agriculture Production Index (API) within its annual Economic and Social Survey of Jamaica. The API is estimated for export and domestic crops, meat & poultry, and fisheries sub-sectors, as well as producing a value for the whole sector. The API is a useful means of comparison of the growth or decline in the sector year on year.

Overall, there was a 15.3% increase in production in the agricultural sector in 2006 compared with 2005, with increases across all sectors (Table 4.5, also graphically in Figure 4.2). The 15.9 percent growth in real GDP for agriculture from 2005 to 2006 was largely due to favourable weather conditions as well as the implementation of private sector and government-led initiatives aimed at improving production and productivity in the sector.

Table 4.5: Agricultural Production Index for Jamaican Agriculture (1986 to 2006; 1986=100)

Year	Export Crops	Domestic Crops	Meat & Poultry	Fishing	Total
1986	100.0	100.0	100.0	100.0	100.0
1987	111.8	104.3	103.3	98.3	105.0
1988	98.4	93.6	110.4	97.2	96.3
1989	119.4	88.3	112.9	98.3	95.9
1990	113.1	97.6	130.2	107.0	101.3
1991	121.5	98.0	127.0	103.9	103.9
1992	127.8	119.7	131.1	109.1	118.3
1993	129.6	139.2	124.5	114.5	130.5
1994	133.1	153.0	125.0	114.4	140.2
1995	138.8	161.0	126.6	114.4	146.5
1996	151.8	170.2	127.3	114.4	154.5
1997	128.3	134.9	134.2	106.3	130.2
1998	112.1	131.7	127.5	100.9	124.1
1999	118.4	135.1	151.6	89.3	129.6
2000	104.9	110.1	153.6	79.5	112.3
2001	104.6	119.4	157.4	76.2	117.9
2002	96.7	122.3	171.0	89.0	111.1
2003	90.3	120.0	172.3	82.5	118.0
2004	85.2	101.2	169.2	92.2	106.6
2005	57.7	97.5	176.9	94.7	100.6
2006	85.0	112.8	163.4	141.9	116.0

Figure 4.2: Agricultural Production Index for Jamaican Agriculture (1986 to 2006; 1986=100)

Over the period 1986 to 2006, it is only the meat and livestock sector that displays a consistent upward trend, although production in this sector actually declined in 2006. All the other sectors show increasing production until the mid-1990s, after which the export and domestic crop sectors and the fishing sector show significant declines. Thus, the export crop sector API value fell to below the 1986 value in 2002 and has remained below this threshold since. For domestic crops, the decline has been just as significant, with production falling to 1986 levels during 2004/05, recovering somewhat in 2006. For the fishing sector, the base of the decline was in 2000/01, after which there has been some recovery, most significantly in 2006.

Export Agriculture grew by 47.4 % in 2006. The growth was due mainly to improved performances in Sugarcane, with a 27.5 % increase in sugar cane milled, and other main export crops such as cocoa and coffee where production grew by 8.2 %, and 39.3 % respectively. Banana grew by 180.5 % from the very low levels of production in 2005 due to Hurricanes Ivan, Dennis & Emily. However, the API for this sector remained significantly below the 1986 baseline with a value of 85.0 %

Domestic Agriculture showed a growth of 15.7 % in 2006. The increase in this sub-group was due to an increase in production of plantains by 145.6 %, fruits by 32.4 %. Other increases in production included legumes by 12.1 %, both vegetables and yams by 14.6 % as well as other tubers (e.g. cassavas) by 29.2 %.

As commented above, the meat and livestock industry declined in 2006. This was due to increases in input cost as well as praedial larceny which affected farmers islandwide. Declines were recorded in beef cattle, pig rearing, goat and mutton. However, poultry production increased, on the back on retooling in 2005, continued improvements in production efficiency and increasing local demand.

Fisheries showed significant growth in 2006, on the back of relatively slow growth from 2001.

4.2.4 The Importance of Climate to Jamaican Agriculture

The mean rainfall and temperature in Jamaica are presently 1786mm and 28^{o}C respectively (Spence, 2008). The climatic requirements of rainfall and temperature for the main export and domestic crops of Jamaica is summarised in Table 4.6. Current climatic conditions are optimum or near-optimum for the production of these crops – both in terms of growing and ripening conditions of the crops, as well as minimisation of pests and diseases. It is the climatic variability and extremes experienced in Jamaica – in terms of tropical storms/hurricanes and the occurrence of drought – that present the main climatic challenges to agriculture in Jamaica.

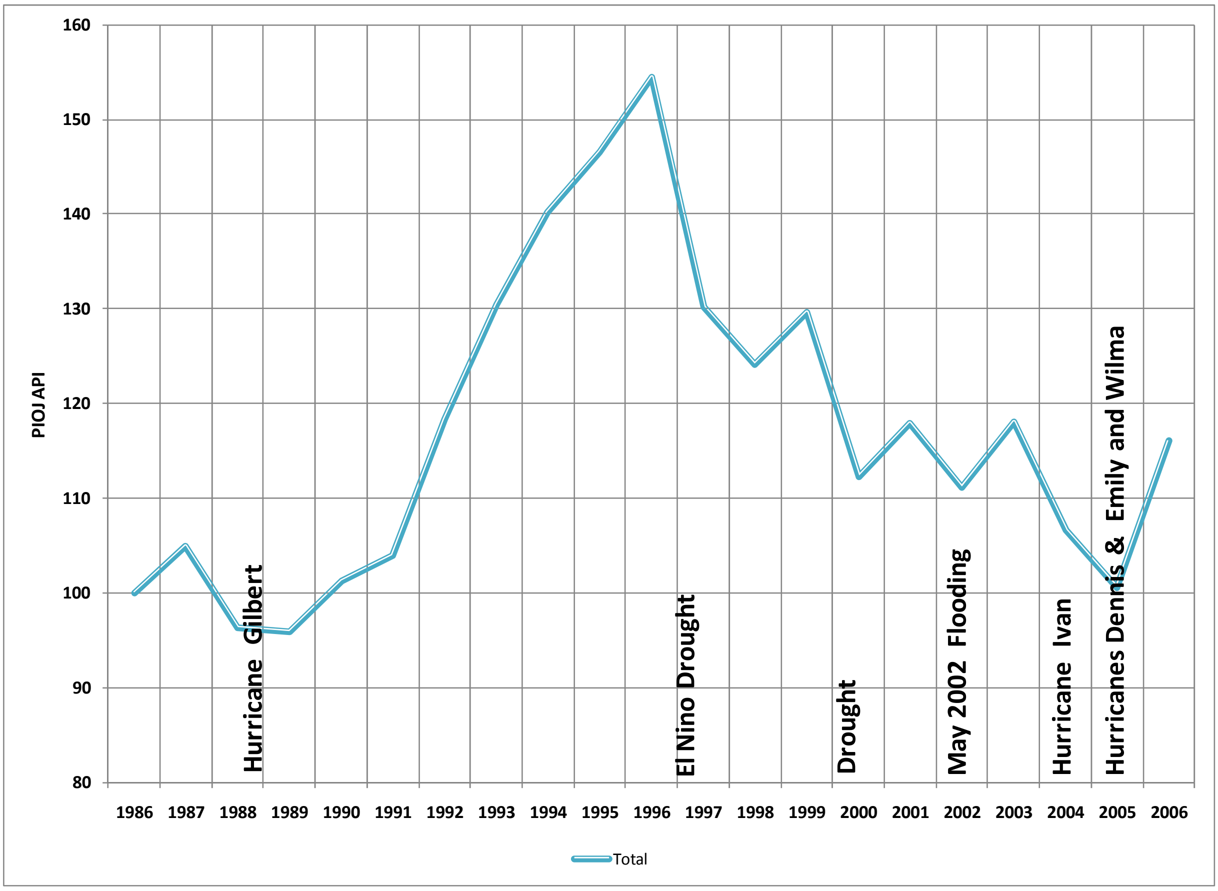
Table 4.6: Average Main Climatic Requirements of the Main Export and Domestic Crops of Jamaica

Crop	Average Climatic Requirements	
	Rainfall / water requirements (mm/yr)	Temperature (^{0}C)
Sugar Cane	1100 to 1500	30-34^o C
Banana		27^{0}C optimal
Coconut	1000 to 2250	27^{0}C optimal with diurnal variation of 6^{0}C to 7^{0}C
Citrus	1250 to 1850	28 to 32^0 C
Pimento	1500 to 1700	18 to 24^0 C
Cocoa	1250 to 3000	18-21^0 C min, 28-32^{0}C max
Pineapple	700 to 1000	23-24^0 C optimal
Yam	Approx. 1000	25-30^0 C
Cassava	Approx. 1500	25-29^0 C

Furthermore, with projected decreases in precipitation of up to 40 percent and up to 2.8ºC rise in temperature expected by 2080s (Table 4.2), it can be seen that many crop will be growing under borderline conditions and therefore will be under stress. Food security will be threatened.

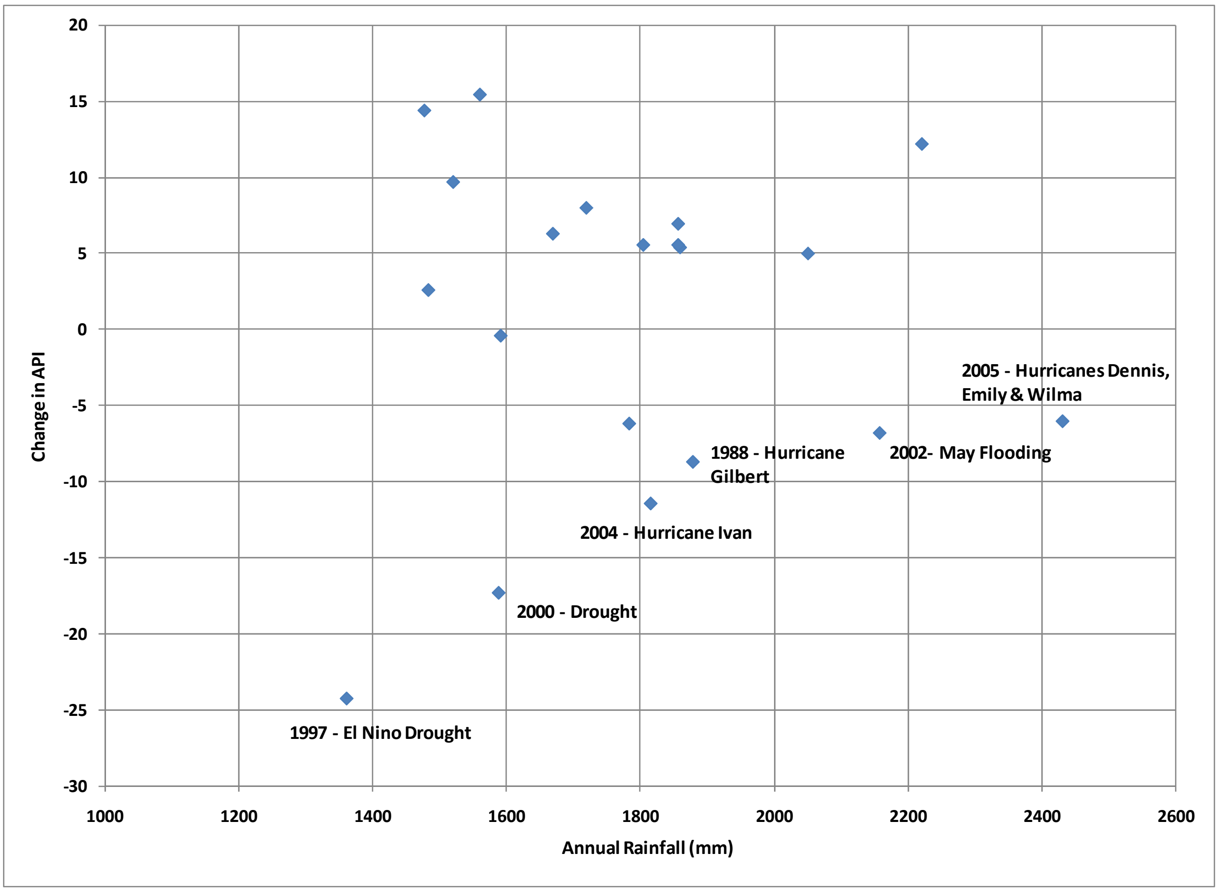
Values of the Agricultural Production Index (API) for the agricultural sector as a whole from 1986 to 2006 are presented in Figure 4.3. Also plotted are the occurrences of major climatic events that have occurred in the same period. There would seem to be a clear association between the occurrence or lack of occurrence of these climatic events and the performance of the agricultural sector. For example, following Hurricane Gilbert there was a period of significant growth from 1989-96. However, in the following decade, the API has steadily declined, with this decline associated with the occurrence of droughts in 1988 and 2000, followed by significant flooding in 2002, and the passing of Hurricane Ivan in 2004, followed by Hurricanes Dennis, Wilma and Emily in 2005. The sector showed significant rebound in 2006, but has been severely impacted by the passage of Hurricane Dean in August 2007. Other factors have an impact on the performance of the agricultural sector such as government policies as well as world market prices for crops, but it is the occurrence of climatic events that demonstrate the vulnerability to current climate of Jamaican agriculture.

Figure 4.3: Agriculture Production Index and Major Climatic Events (1986to 2006)



Additional analysis compared changes in API year on year plotted against annual rainfall (Figure 4.4). The aim of this analysis was to identify the presence or otherwise of any thresholds in the annual rainfall and changes in the API. As can be seen, it is difficult to identify any significant relationships between annual rainfall and API other than droughts are associated with greatest declines in API compared with impacts associated with tropical storms. This reflects the longer term and wider spatial impacts on agriculture from drought compared with the immediate and smaller spatial impacts associated with tropical storms in Jamaica.

Figure 4.4: Agriculture Production Index and Annual Rainfall (1986 to 2006)



<u>Economic Costs to Agriculture from Tropical Storms/Hurricanes</u>

Estimates of the costs, both direct and indirect to agriculture from the passage of tropical storms and hurricanes are presented in Table 4.7. Direct losses are due to the destruction of agricultural assets, livestock, crops and agricultural infrastructure, while indirect losses are due to reduction in productivity and future output losses due to the disaster damage.

Table 4.7: Estimates of Direct and Indirect Costs to Agriculture from Recent Storm Damage

Storm / Hurricane	Direct Losses (J$)	Indirect Losses (J$)	Total (J$)
May 2002 Flooding (1)	J$578M	J$205M	J$783M
Hurricane Ivan (2)	J$3407M	J$5143M	J$8550M
Hurricanes Dennis & Emily(3)	J$380M	n/a	n/a
Hurricane Wilma (4)	J$248M	n/a	n/a
References: (1) Economic Commission for Latin America and the Caribbean (2002); (2) Economic Commission for Latin America and the Caribbean *et al* (2004); (3) Planning Institute of Jamaica (2005a); (4) Planning Institute of Jamaica (2005b)			

Estimates of losses by sub-sector and major crop are presented in Table 4.8 for these same events, and highlight the variations in vulnerability between the different sectors to these tropical storms / hurricanes. Traditional export crops include banana, coffee and sugar.

Table 4.8: Estimates of Direct Costs to Different Agricultural Sectors from Recent Storm Damage

Storm / Hurricane	Livestock	Domestic Crops	Traditional Export Crops	Comment
May 2002 Flooding (1)	J$100M	J$351M	J$68M	Vegetable losses greatest at J$138M
Hurricane Ivan (2)	J$607M	J$199M	J$2001M	Coffee losses greatest at J$992M
Hurricanes Dennis & Emily (3)	J$30M	$112M	J$237M	Coffee losses greatest at J$153M
Hurricane Wilma (4)	J$42M	J$206M	N/A	N/A
References: (1) Economic Commission for Latin America and the Caribbean (2002); (2) Economic Commission for Latin America and the Caribbean *et al* (2004); (3) Planning Institute of Jamaica (2005a); (4) Planning Institute of Jamaica (2005b)				

Hurricane Ivan had by far the greatest economic impact on the agricultural sector. The impacts of Ivan illustrate some of the specific vulnerabilities that crop-types face with respect to the occurrence tropical storms/hurricanes. These are illustrated below, focussing on traditional export crops (Economic Commission for Latin America and the Caribbean *et al*, 2004).

Sugar Cane: Strong winds and the floods from the heavy rainfall affected this crop at a time when efforts were being made to increase the area of recently planted fields, improve reaping conditions, and increase the sugar-to-cane production ratio. Sugar canes were broken and uprooted and flooding affected extensive areas. In addition, miscellaneous infrastructure and irrigation systems sustained damage and destruction. Losses for the processing of cane and its conversion into sugar also occurred due to the higher water content of the cane.

Banana: The winds of Ivan inflicted heavy damage to virtually the entire area devoted to banana plantations in Jamaica. Trees were broken or uprooted in an estimated surface area of 4,272 hectares (*see image, right*), and the entire production of bananas for export and for domestic consumption was lost. Plantations can be resuscitated and full production can be achieved after 6 to 9 months. In addition to the loss of production, there was a negative impact on employment. Other than the limited labour that will be required for the rehabilitation of the plants and farms, nearly 8,000 persons were out of work. As the new banana plants reached maturity and began production, workers were able to return in a staged fashion.

Coffee: The strong winds brought by Ivan caused the breaking up or uprooting of coffee trees as well as damage to the forest that provides shading to the plantation. In addition, the winds caused the loss of berries for the current crop in the Blue Mountain and lowland coffee areas. This caused a major setback to the increased coffee production that had been achieved as a result of major resuscitation of coffee trees activities by farmers. It was estimated that 5 percent of the coffee tree population was destroyed. This is especially significant, as new coffee trees only begin producing when they reach maturity at the age of three to five years. The winds also caused the loss of berries in nearly 45 percent of the coffee-producing area. It was estimated that this impeded the production and export of 213,000 boxes of Blue Mountain coffee and 41,000 boxes of lower quality coffee.

An insurance scheme for the sector was operating at the time of Ivan. Coffee production is insured provided the losses occur after berries are present in the trees, at the then rate of US$ 20 per box for Blue Mountain coffee and US$ 12 per box for lowland coffee, to a combined maximum amount of US$ 8.8 million. The coffee trees were not insured since the premiums are considered too high. Reinsurance was available from a number of large international insurance groups – including Munich Re – whenever the losses exceed 20 percent of the expected crop. However although, insurance proceeds assisted coffee growers to recover part of their losses, some producers that were already considering withdrawal from this activity due to the low international prices, decided not to continue their production.

Cocoa: Efforts were being made in 2003 to increase production to take advantage of increasing international prices and demand. However, the scarcity of rains in the first half of 2004 resulted in reduced production by almost 50 percent. The hurricane damaged trees and compromised the corresponding future production of cocoa in an area of 1,100 hectares, thus compounding the problems of the farmers.

Pimento: These production activities sustained significant damage and losses. Physical infrastructure – including warehouses and equipment – and stocks of pimento already processed were damaged or destroyed as well as trees destroyed and berries lost.

Citrus: The action of the strong winds caused the loss of many fruits that were in varying degrees of ripening.

Economic Costs to Agriculture from Droughts

There is no equivalent methodology or reporting of the socio-economic impacts of drought events on the agricultural sector and the wider Jamaican society as found with the reports that have been prepared since 2002 by Economic Commission for Latin America and the Caribbean and the Planning Institute of Jamaica. Therefore, reviewing and estimating costs of drought to agriculture difficult. In terms of impacts of droughts on Jamaican agriculture, there are the direct costs associated with loss in yields, as well as decline in the quality of crops harvested. For the wider Jamaican economy and trade impacts there is the increase in food imports to meet local demand which cannot be met by drought affected agriculture.

Chen *et al* (2005) included an analysis of sugar cane yields from the Worthy Park Plantation in the upper part of the parish of St. Catherine in their review of agricultural drought in the West Indies. This plantation is rain-fed and therefore yields are closely linked with climate and precipitation. They pointed out that four climate related stresses lead to a poor harvest of sugar cane in Jamaica. These were:

- Below normal July-September precipitation – this has a telling impact on sugar cane growth;
- Below normal November-May precipitation, resulting in the poor establishment of plantings and retardation of early growth (although there can be some recovery in sugar yields with above average July-September precipitation);

- Above normal temperatures and excessive precipitation during November-March (in the 4-6 weeks before harvest) which is unfavourable to ripening of the cane;
- Excessive spring rains in poorly drained, flood prone areas.

Their analysis of 50 years of sugar cane yields highlighted the link between the occurrence of these climate phenomena, El Nino and La Nina events, and reduced sugar cane yields. For example, the June-October 1991 precipitation was 46 percent of normal, which was followed by precipitation at 61 percent of normal during December 1991-February 1992, as well as minimum temperatures 102.8 percent of normal during November 1991-March 1992. This resulted in a 1992 sugar cane yield at 81 percent of the 1950-99 yields. Therefore, by analogy, climate change would be expected to have significant impacts on sugar cane yields, although further studies would be necessary to quantify the impacts on sugar cane and other crops and develop adaptation strategies.

In terms of national impacts, some inferences can be made from available statistics. In 1997, where annual rainfall for Jamaica was only 67.5 percent of the long term 1951-80 average, the volume of selected traditional exports totalled 283,688 tonnes, earning approximately US$212.6 million. This compares with export volumes of 307,796 tonnes and earnings of US$224.9 million in 1996. There was a decline in export earnings of some US$12.3 million, although earnings per tonne increased by 2.6 percent in 1997. During this same period, the value of selected food imports increased from US$154.8 million in 1996 to US$175.6 million in 1997 (13% increase) while the volumes of imported foods increased by 5.4 percent. However, not all of these changes can be attributed to the 1997 drought alone, as there were significant changes in rice and maize prices, which also impacted on the volumes and value of the total food imports.

This simple example illustrates some of the difficulties in estimating costs of drought to Jamaican agriculture, but also the order of magnitude of the costs to agriculture from such events. It is clear that a methodology to understand and estimate the costs of drought to agriculture in Jamaica is required. Such cost estimation would assist quantifying the impacts, identifying those sectors most vulnerable to drought and therefore assist in the development of long term adaptation strategies for these sectors.

4.2.5 Analysis of Future Climate Risks for Jamaican Agriculture

There are various methods available to assess the impacts of climate, climate change, and climate variability on the agricultural sector. These are summarized in Table 4.9, along with the respective strengths and weaknesses.

Table 4.9: Climate Impact Agricultural Assessment Methods

Type of Model	Key Characteristics
Agro-climatic models and GIS	Based on simple calculations and effective for comparing across regions and crops, but only consider climate
Statistical models and yield functions	Based on empirical relationships between crop responses and climate, but do not explain causal mechanisms nor future climate crop relationships
Process-based models	Include climate, soils, and management. Widely used and calibrated and can be used for adaptation assessments. Require significant data input for best results
Economic models	Incorporate land values, commodity prices and economic outcomes, and therefore useful to assess market based and financial adaptation measures – but are complex and require significant data input
Household and village models	Look at current coping strategies under existing conditions, but do not capture future stresses if different from current

Limited work to date has been undertaken in Jamaica on adopting these approaches to investigate the impacts of climate change on key cash and food crops in Jamaica. Some initial work has been carried out by researchers at the University of West Indies in Jamaica on climate and sugar cane yields. (Amarakoon, personnel communication, 2008). However, this has not progressed to a level that allows quantitative assessments to be carried out with respect to climate change on sugar cane yields.

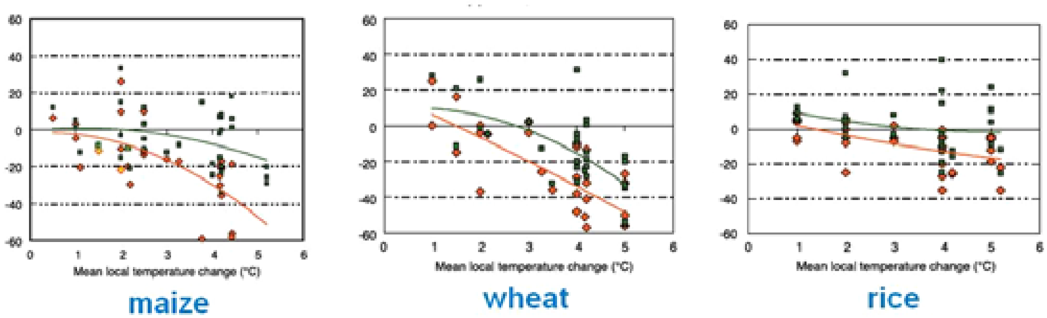
Progress has started in the training of staff in the use of modelling approaches to investigate climate and climate change on crop yields. For example, in April 2008, top researchers from a wide range of Caribbean countries including Jamaica, gathered in Georgetown, Guyana, for intensive technical training in the assessment of climate change impacts in the agricultural sector. The purpose of this training was to be better able to provide decision-makers in each country and at the regional level with scientific data to guide development planning. The training workshop was conceptualized and organized by the CARICOM Climate Change Centre (CCCCC), in close coordination with Cuba's National Institute of Meteorology (INSMET). The momentum generated by this exercise needs to be capitalized upon to develop further the technical capacity to undertaken the necessary studies for key Jamaican crops and thus inform adaptation policy development and implementation.

Given the lack of in-country studies and tools to develop specific risk assessment results for Jamaican crops and livestock, a literature review approach was undertaken to present the findings of studies of key crops and livestock in terms of impact assessment using an analogue approach. This literature review is not intended to be exhaustive, but it is considered that it provides useful results with respect to the likely range of impacts that might be expected for the Jamaican situation, and also illustrates the role of socio-economic factors in the assessment of the overall impacts under future scenarios on crop yields and production. It also provides an indication of the range of modelling approaches that have been adopted by different countries in the preparation of their own V&A studies.

IPCC (2007a) includes a chapter discussing the impact of climate change on the food (see Chapter 5: Food, Fibre & Forest Products). Summaries of the results are presented for a range of food crops. However, it is interesting to note that there are few studies included within the report that focus on food and cash crops that are important to Jamaica and other Caribbean countries. For example, Figure

4-5 presented here is extracted from IPCC (2007a) Chapter 5 and presents the results from the pooling of 69 studies looking at the impact of climate on cereal yields (maize, wheat and rice).

Figure 4.5: Percentage cereal yield change with mean local temperature change for maize, wheat, and rice for low latitudes



(Notes: Studies without adaptation red dots, with adaptation green dots. Polynomial best-fit lines summarise results only and are not for predictive purposes)

The results provide useful information on the likely range of impacts of climate change on these cereal yields and also the potential impact of adaptation measures to counter potential declines in yield from in these cases increased mean local temperatures. However, it is clear that Jamaica needs to undertake and promote the results from its own studies and assessments to build up a similar database of research to assist with in-country and region-wide V&A studies and resulting policy development.

In the absence of studies specific to Jamaica or the Caribbean, examples were drawn from the literature on studies relevant to the agricultural sector in Jamaica. This includes sugar cane, coffee, banana, yam and livestock, as examples of the range and scope of studies that are required for Jamaica. .

Sugar cane: Sugar cane is a significant crop for Jamaica and its growth is closely related to climatic variables. The optimum temperature for germination = 30°-34° C, optimum temperature for ripening = 12°-14° C, optimum rainfall = 1100-1500 mm/yr. The incidence of sugar cane diseases and pests are also temperature related. Smut initiation and spread is high at ambient temperatures of 25°-30° C, spread of red not disease is high at 37°-40° C, while rust incidence is high when the minimum temperatures are reduced. Shoot fly incidence is high in summer when the air temperatures are very high and when diurnal temperature range is low.

Climate modelling projections for 2050 indicate both increased temperatures (approx. +1.30C) and reduced rainfall (approx. -6%). The impacts of this are likely to be increased water/irrigation requirements under higher temperatures and reduced rainfall, and thus increased competition for water resources, as well as the increased incidence of pest and disease outbreaks.

There are examples of a range of modelling approaches being used to assess climate, climate change and impacts on sugar cane yield from countries where sugar cane is a key crop. For example, the Republic of Mauritius within its Initial National Communication (1999) outlines work that was undertaken by the Mauritius Sugar Industry Research Institute to assess the vulnerability of the sugar cane crop to climate change without catering for carbon dioxide fertilization effects. The findings were that sugar production was very vulnerable to climate changes. Production decreased by 32- 57% under the scenarios used, mainly as a result of lower water use efficiencies as it was indicated that more than a

20 percent rainfall increase was needed to offset a 2°C rise in temperature. Three adaptive options were evaluated in the research, namely irrigation, a change in variety type, and a change in harvest date. The adoption of irrigation mitigated all impacts of climate change while a change in harvest date had no effect under the present production system. However, the modelling indicated that there could be a beneficial impact on production with the combination of irrigation and a change in harvest date. The change in varieties showed that the genetic potential exists but will have to be incorporated in new varieties to tolerate changes. Additional amounts of water needed for the adoption of irrigation, were available hydrologically, but would be very costly to provide in terms of extension of infrastructure and additional water storage capacity required.

V&A assessments for agriculture in Fiji have been undertaken using an integrated modelling framework, the Pacific Climate Change Impacts Model (PACCLIM)
(http://siteresources.worldbank.org/INTPACIFICISLANDS/Resources/4-Chapter+3.pdf.)

PACCLIM included the PLANTGRO model, which allows the derivation of notional relationships between plant response (suitability) and different levels of 23 climate and soil factors. The outputs can be in the form of:

- Yield: relative yield in relation to potential maximum yield;
- Growing season length (for annual crops);
- Greatest limitation: the most critical limiting factor at a given point in time;
- Overall limitation rating: a composite index taking into account soil and climate conditions in each site.

A three-step approach was taken to assess the impact of climate change on sugar cane production on the island of Viti Levu. This was first to estimate baseline conditions, then estimate future production under climate change and climate variability, and finally to estimate the economic impact of climate change and climate variability. This assessment estimated a 9 percent reduction in yield for 2030-50 compared with 1983-98, equivalent to a decline in the value of the crop of US$13.7M at 1998 prices.

Deressa, Hassan & Poonyth (2005) presented results assessing the impact of climate change on South Africa's sugar cane growing regions. The approach taken here was to use an econometric approach (the Ricardian method), which was first developed in the USA to measure the value of climate in agriculture. The approach allows the economic impacts of climate change to be assessed, as well as the assessment of adaptation measures. It requires time series data on climate, land prices, and productivity. The study pooled data across all sugar cane growing regions, between irrigated and non-irrigated areas. Results from the analyses indicated that sugarcane production in South Africa is highly sensitive to climate change. The impact of an IPCC scenario of doubling carbon dioxide (which would lead to rises in temperature by 2ºC and precipitation by 7%) was negative on sugarcane production in all zones under both irrigation and dry land conditions.

The small margin of difference between reduction in average net revenue per hectare for irrigated systems (26%) and dry land conditions (27%) indicated important implications for the efficacy of irrigation as an adaptation strategy, with the results suggesting that production of sugarcane under irrigation does not provide an effective option for reducing climate change losses in South Africa.

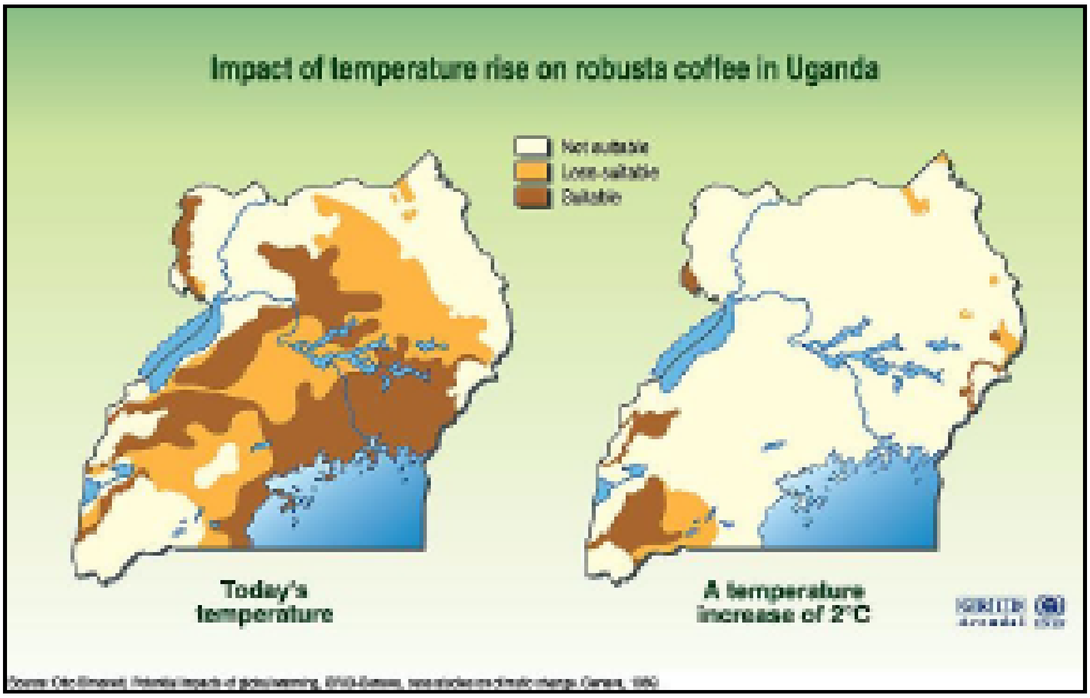
This study was led by researchers based at the Centre for Environmental Economics and Policy in Africa who have recently completed a 3 year programme enhancing the research and policy capacity in Africa, both at the national and regional levels, to improve national and regional assessments of the economic impact of climate change on the agricultural sector of 11 African countries, and to determine the economic value of various adaptation options that can be directly implemented by local farmers to limit the adverse impact on local food supply. The report findings of this programme can be found at http://www.ceepa.co.za/Climate_Change/project.html and represent a significant resource of reference materials on approaches, methods and results to assist future adaptation studies in Jamaica.

Coffee: Studies have been undertaken in a variety of coffee growing countries assessing the impact of climate change on coffee production and yields.

For example, Gay *et al* (2006) adopted an econometric modelling approach to estimate impacts of climate change on coffee production in the Veracruz region of Mexico to 2020. They found that temperature is the most relevant climatic factor for coffee production, since production responds significantly to seasonal temperature patterns. The results for the projected climate change conditions for 2020 indicated that coffee production might not be economically viable for producers, since the model indicated a reduction of 34 percent of the current production. Although different economic variables (the state and international coffee prices, a producer price index for raw materials for coffee benefit, the national and the USA coffee stocks) were considered as potentially relevant, their work suggested that the state real minimum wage could be regarded as the most important economic variable. Coffee production in Mexico is very labour intensive, representing up to 80 percent of coffee production costs. As expected, increments in the price of such an important production factor increase production costs and have strong negative effects on production. This analysis therefore indicates that socio-economic factors as well as climate change has an important impact on coffee production and that climate change impacts should not be assessed in isolation from socio-economic factors.

Studies have also been undertaken in Africa using a relatively simple GIS based approach. For example, Figure 4.6 shows the changes in Uganda of the total area suitable for growing Robusta coffee from a temperature increase of 2°C. This analysis indicates that the areas suitable for growing would be significantly reduced. Only higher areas would remain, the rest would become too hot to grow coffee.

Figure 4.6: Impact of Temperature Rise on Robusta Coffee Production Areas in Uganda



In Tanzania the impact of climate change on coffee productivity is estimated to be mixed (United Republic of Tanzania, 2003). Two areas were selected which represent the major producers in the north-eastern and southern parts of the country. Using a climate scenario of doubling of carbon dioxide, annual average temperature is estimated to increase between 20°C and 40°C in the two areas (assumed to be by 2100), while annual rainfall is estimated to increase by 37 percent in the north-eastern region but decrease by 10 percent in the southern region.

A temperature increase of 20°C in both areas is within the optimal range for coffee growth, the major determining factor on changes in yield is rainfall. An increase in rainfall implies an increase in the yield. In the southern areas, the decrease in rainfall is minimal and is estimated to have a minimal impact on yield. Therefore, according to the study, given these estimated changes in temperature and rainfall, yield is estimated to increase by an average of 17 percent in each area. If the annual average temperature increase is closer to 40°C, this would result in the need for irrigation to supplement reduced rainfall. An alternative adaptive approach that is recommended is to develop drought and disease resistant coffee varieties with farmers sensitized to use them if coffee is to remain a major cash crop in these areas. The overall conclusion from the study was that coffee is likely to be grown successfully where rainfall is estimated to increase i.e., in the northern, north-eastern and south-eastern parts of Tanzania.

Banana: Another study undertaken by the Centre for Environmental Economics and Policy in Africa focused on looking at changes in crop water requirements for a range of crops across six districts of Kenya (CEEPA, 2006). The crops investigated included banana, as well as maize, beans and potatoes. For the study, CROPWAT was used to assess changes in crop water requirements fewer than four climate change scenarios results from two models, with annual average temperature increases up to +40°C with annual average rainfall changes of +/- 20 percent. The results produced for banana were typical of the study results as a whole, which highlighted that for a given crop type, crop water requirements were location specific owing to the marked variability in the agro-ecological characteristics of the study districts. These conclusions re-affirm the need for country and crop specific studies for Jamaica.

Yam and Cassava: The study that investigated sugar cane in Fiji also looked at the potential impacts of climate change on yam and cassava productivity on the island of Viti Levu using the PLANTGRO model in PACCLIM. Six climate change scenarios were considered, comparing yields under current climate with those estimated for 2050. This was based on occurrences of El Nino and La Nina for both current and future climate and the impact such occurrences have on crop yield. In the case of yam, the study estimated changes in yield of between -15.4 percent and +0.8 percent by 2050, while for cassava, the range was from -11.0 percent to +4.3 percent by 2050.

Livestock Production: Climate change impacts on animal husbandry in Africa were investigated by the Centre for Environmental Economics and Policy in Africa (CEEPA, 2006b) using the same economic approach described earlier by Deressa, Hassan & Poonyth (2005). In this study, net revenue from raising animals on small and large farms across Africa was regressed on climate, soils, and other control variables to test the climate sensitivity of livestock in Africa. The study was based on a survey of over 9,000 farmers across 11 countries. From this dataset, 5,400 farms were found to rely on livestock. The farms were split into two groups: small farms that tended to be more labour intensive, relying on native stocks and with few animals; and large farms that tended to be more commercial operations, with much larger stocks and more modern approaches to production.

The analysis showed that livestock net revenues of large farms in Africa fell as temperatures rose but that small farms were not temperature sensitive. In addition, it was found that higher temperatures reduced both the size of the stock and the net revenue per value of stock for large farms. However, for small farms, higher temperatures did not affect the size of the stock and the net revenues per value of stock increased. This indicates that large farms in Africa are vulnerable to global warming but small farms are not. It is likely that large farms are vulnerable because they rely on species such as beef cattle that are not well suited to high temperatures. Small farms are not vulnerable because they can substitute species such as goats that can tolerate high temperatures.

The analysis also indicated that increased precipitation reduces livestock net revenue per farm for both small and large farms. The elasticity of net revenue per farm is particularly large for small farms. Further analysis indicated that increased precipitation reduces both the size of the stock and the net revenue per animal owned. Although higher precipitation generally increases the productivity of grasslands, it also leads to the conversion of grasslands into forest. Further, animal diseases are likely to increase with warm wet conditions. Finally, as precipitation increases, many farmers find it advantageous to shift from livestock to crops. The positive side of these precipitation findings is that if precipitation declines, livestock net revenues will increase, especially for small farmers. The study concluded that livestock provides an important agricultural adaptation against reductions in precipitation should they occur.

4.2.6 Proposed Elements of an Agriculture Adaptation Strategy for Jamaica

As demonstrated by this brief literature review, there are already a substantial number of V&A studies under climate change and climate variability that have been carried out in various countries looking at crops that are important to Jamaican agriculture. It is therefore important that the Jamaican agricultural sector develops the technical and managerial capacity, as well as funding, to support similar climate impact agricultural assessments to first understand how vulnerability is likely to vary under future climate change and climate variability, and then to take these studies forward to investigate possible adaptation strategies as part of a wider adaptation programme for the agricultural sector.

A number of key recommendations on the way forward to address issues of climate vulnerability and the development of adaptation projects, programmes and policy were developed as part of the V&A analysis. These recommendations were presented at a stakeholder workshop in March 2008 for review, comments, and ranking. The ranking was based on a simplified multi-criteria analysis approach that included considerations of relative cost of recommendations, effectiveness of proposed solutions, technical / skills availability for implementing the recommendations, technology, and number of beneficiaries, political and social acceptability, environmental impact, and consistency with objectives of the National Development Plan. The scores provided by three breakout groups were averaged.

<u>Recommendations for the Agriculture Sector</u>

The climate change adaptation recommendations for the agriculture sector are presented in Table 4.10 including the workshop rankings. A ranking of 1 gives the most preferred option.

Table 4.10: Climate Change Adaptation Recommendations for the Agriculture Sector

Recommendation	Justification	Responsibility	Workshop Pooled Ranking
Leverage and co-ordinate international funding to maximize benefits within the Agricultural Sector	Significant investment is required in a number of areas within the sector. If multi-lateral grant-aid & bi-lateral soft loans are to be used to support this work, then the benefits accrued must be maximized, both in outputs and capacity building.	Ministries of Agriculture and Land and International Trade, Finance and Planning, PIOJ.	**1**
Improve access to loan / grant funding to domestic crop producers.	Historically this sub-sector has not received the same magnitude of financial support as has the export sub-sector, yet it is important for food security and rural incomes, and to provide funds to allow these producers to adapt to climate change This will lead to the empowerment of domestic producers.	Ministry of Agriculture & Lands, RADA, Development Bank of Jamaica, PIOJ, Funding and financial agencies.	**2**
Raise awareness of the potential impacts of climate change on the agricultural sector , food security and cultural practices	Climate change is not mentioned in the Agricultural Development Strategy 2005-2008 documentation. This suggests that the potential impacts of climate change on the agricultural sector have not yet informed agricultural policy & practice	Ministry of Agriculture & Lands, with support from Met Service and others (e.g. UWI climate modeling group) as well as Tertiary Institutions and Farming Organizations.	**3**
Review approaches to integrated cropping and management systems under climate change	Existing pest management strategies may require modification under climate change. Care must be taken that any changes to these strategies do not have negative impacts on the environment e.g. increased pesticide use	Ministry of Agriculture & Lands, Research Institutes, Industry Bodies, RADA, international and regional organizations.	**3**
Develop regional links to fund & promote plant breeding programmes for common crops and livestock	Adaptation strategies include the development of crop varieties with increased temperature, changes in wind regimes, drought and pest resistance. This is a costly exercise, best undertaken as a co-operative programme across the Caribbean.	Ministry of Agriculture & Lands, Research Institutes, UWI, CARDI, IICA and ACP countries. Regional institutions and international organizations.	**5**

Recommendation	Justification	Responsibility	Workshop Pooled Ranking
Support & fund increased water use efficiency across irrigated agriculture	Improved water use efficiency will reduce demands on existing sources and infrastructure, reduce costs and reduce vulnerability to drought.	NIC and other Ag. water providers and consumers	**5**
Support & expand funding of the IWCAM programme as well as internationally hosted coastal zone management and other related initiatives.	One of the benefits of improved land use management practices is protection of water resources – quantities and quality. It is rural and agricultural communities that will have a key part to play here at the farm and local village scale.	NEPA, WRA, NWC, Ministry of Ag & Lands, PIOJ, Forestry Dept and RADA.	**7**
Initiate Climate Change Working Group for Agriculture	There is a need to co-ordinate efforts across the sector, to provide focus and direction for research & policy development including a global focus on world market trends on food production and food security	Ministry of Agriculture & Lands to lead supported by Research Institutes, Industry bodies.	**8**
Develop modeling approaches and tools to allow assessment of impacts of climate change on export & domestic crops and meat production	Analogue approaches have been used in this study to illustrate the potential impacts of climate change on major crops in Jamaica. Detailed crop / country / climate specific assessments are required to inform adaptation programme and policy development	Ministry of Agriculture & Lands, Research Institutes, UWI, CARDI, IICA and ACP countries	**9**
Review role of financial instruments to provide insurance protection to key sub-sectors	Access to insurance products may provide one method of adaptation to key sub-sectors, although their operation and expense must also be considered under climate change	Ministries of Agriculture and Land, Finance and Planning, insurance agencies and brokers, farmers' organizations.	**10**

Additional comments and feedback were received from the working groups:

- The "Jagdeo Initiative" presented by the President of Guyana in 2005 to CARICOM Heads of State provides a framework for the sustainable development of agriculture throughout the Caribbean and has identified the need to adapt to the potential impacts of climate change in the region, as well as stabilizing regional food security;
- The use of economic instruments to assist with adaptation and changing practices and behaviour was raised, particularly focused on domestic crop and livestock producers;
- Wastewater reuse for the agricultural sector was raised as a possible underused water resource, including flushing effluent from fish farming onto nearby lands;
- The need for a National Climate Change Committee was emphasized.

The highest placed recommendation proposed developing mechanisms to maximize benefits to the agricultural sector from international funding. This was followed by the recommendation to improve access to loans and grants for domestic crop produces. There are two recommendations ranked equal third: one to raise awareness of the potential impacts of climate change on the agriculture sector and one to review approaches to integrated cropping and management systems under climate change.

The recommendations receiving the lowest scores were the setting up of a climate change working group for agriculture (although one group placed this second), and the proposed development of modelling approaches and impact assessment tools (which the preparation of the this report has been shown to be a significant gap in the knowledge base to aid decision making), and the proposed review of the role of financial instruments to provide insurance protection. This last ranked option was placed last by two of the three groups.

4.2.7 Agriculture Vulnerability and Adaptation Assessment Constraints

Much of the assessment for the agriculture sector was qualitative in nature, although some quantitative analysis was presented such as estimates of the costs to agriculture resulting from Jamaica's climatic variability and the impacts from the passage of tropical storms and hurricanes.

There are also a number of other important initiatives and projects whose findings and outcomes would have greatly strengthened the analyses. These included:

- The MACC funded pilot Vulnerability and Capacity Assessment study in Southern Clarendon that brings climate change, sea level rise, water resources, and agriculture within a single project;
- The IWCAM project focusing of watershed and land management issues.

Necessary technical training and capacity building within the agricultural sector on approaches to impact assessment and adaptation development began with the attendance of Jamaican representatives at a regional training session in Guyana in April 2008. Such activities should be encouraged, supported and expanded since they will inform policy development and decision making with respect to understanding existing and future vulnerabilities of Jamaican agriculture and how best to counter these vulnerabilities while at the same time ensuring increased food security.

4.3 The Water Resources Sector

Jamaica is characterized by a series of mountain ranges orientated along the major axis of the island. The mountains in the east generally have elevations in excess of 1000 m; the highest peak at 2,257 m. The southern half of the island contains major alluvial lowlands associated with coastal swamps.

4.3.1 Geology, Hydrogeology and Hydrology of Jamaica

Jamaica's physiography closely reflects the three major rock types of which it is composed. These rock types are, in chronological order (youngest to oldest):

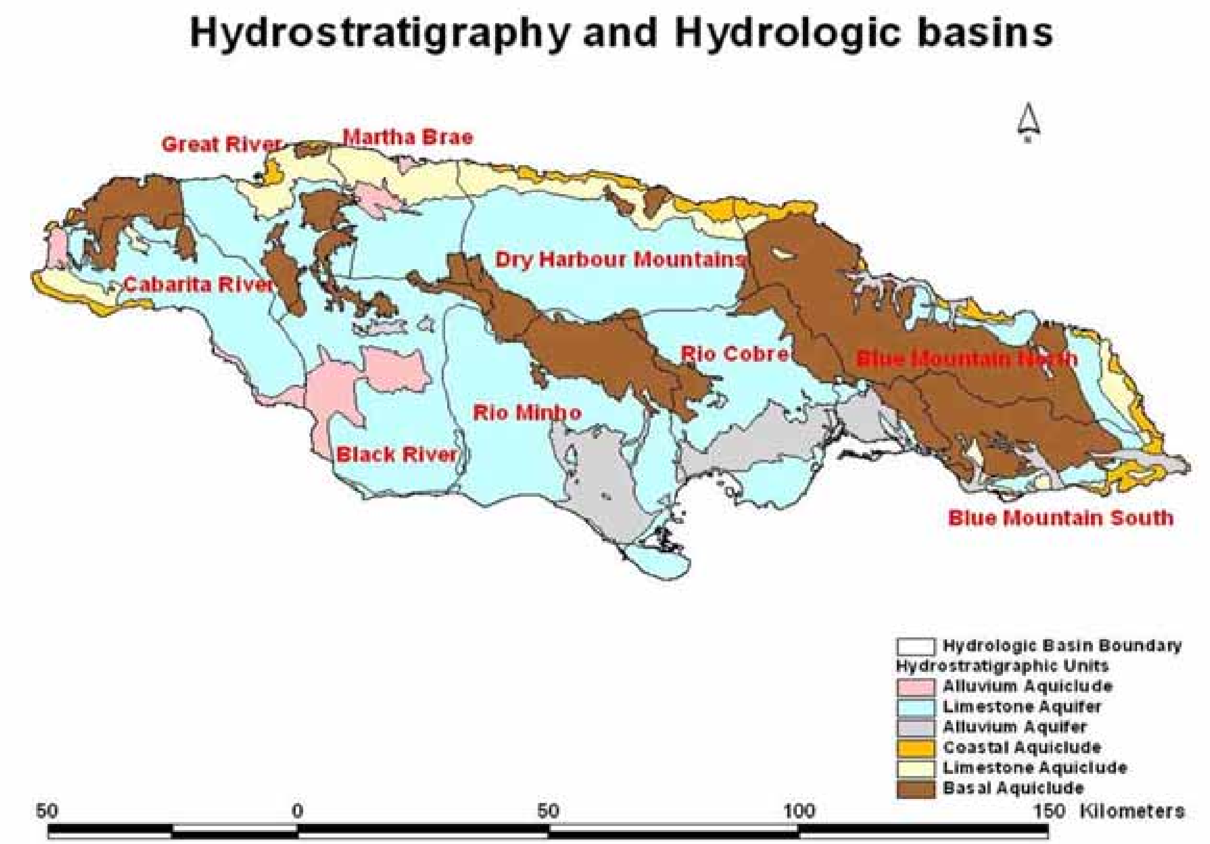
i.	Late Tertiary to Early Quaternary alluviums of generally moderate permeability, which occupy about 15 percent of the land area – mainly in the coastal plains and floors of interior valleys.
ii.	Tertiary limestone with variably developed karstification (i.e., with irregularities from erosion) and moderate to high permeability, which occupy about 60 percent of the land area.
iii.	Cretaceous volcaniclastics of low permeability, which occupy about 25 percent of the land area – mainly within inliers along the upland axis.

The geologic units of Jamaica are divided into either *aquifers* (i.e., an underground layer of water-bearing permeable rock) or *aquicludes* (i.e., a solid, impermeable layer that lies under or over an aquifer). The following hydrostratigraphic units have been identified and their distribution across Jamaica is presented in Figure 4.7.

- Basal aquiclude – Comprises volcaniclastic and limestone rocks on which the other units are deposited. It occupies about 25 percent of the island's surface area outcropping mainly in the Blue Mountains to the east and along the central spine of central and western Jamaica. The basement aquiclude outcrops are related to dense surface stream networks which have high peak flows in the wet season and low peak flows in the dry season.
- Limestone aquifer – Comprises highly karstified limestone. The limestone aquifer rests uncomfortably on the basement aquiclude and thickens towards the coast. It occupies about 50 percent of the island's surface area. The limestone aquifer outcrops are related to an absence of surface streams and to well-developed subsurface drainage systems. This is due to the high infiltration capacity of the limestone aquifer
- Limestone aquiclude – Comprises fine grained chalk and occurs as a coastal band. The limestone aquiclude functions as a subsurface barrier and creates subsurface groundwater reservoirs within the limestone aquifer. This accounts for the high stream flows in the dry season of rivers draining limestone aquifer areas.

• Coastal aquiclude. Comprises soft marls which are patchily distributed along the coast. It functions as a subsurface barrier to pond groundwater within the limestone aquifers.
• Coastal aquifer. Comprises raised reefs patchily distributed along the north coast.
• Alluvium aquifer. Comprises the upper sequences of coastal alluviums in the Rio Minho, Rio Cobre, Kingston, and Blue Mountain Basins. • Alluvium Aquiclude. Comprises interior valley clays.

Figure 4.7: Jamaica's Hydrostratigraphic Units



Source: http://www.geocities.com/watercaribbean/23.html#TNC

The central mountain ranges form the main watershed for rivers which drain either to the north or the south coasts. Surface runoff predominates on outcrops of basement rocks and interior valley alluviums, whereas groundwater is the dominant water resource associated with the karstic limestone and coastal alluviums. The surface water resources are characterized by a marked seasonal variability in flow.

Streams flowing northward originate mainly in the tertiary limestone. These are mostly perennial rivers, like the Martha Brea and White Rivers, with significant base flow components and low seasonal flow variability. Exceptions are the Great River and several rivers in the Blue Mountains (North) Basin, which, like many of the south draining rivers, are characterized by widely varying seasonal flows and comparatively low base flow. Some of their catchments consist of cretaceous volcaniclastics of low permeability. The Black River drains a predominantly limestone catchment.

Hydrological Basins and Watershed Management Units

Jamaica is subdivided into ten major hydrological basins. A basin is a geographical area drained by a particular surface water and/or groundwater system. The basin boundaries are defined such that there is no flow from one basin to another. The basins are further sub-divided into 26 watershed management units (WMU). The WMUs and basins are presented in Figure 4.8 and listed in Table 4.11. Also presented in Table 4.11 are estimates of key hydro-meteorological variables.

Figure 4.8: Jamaica's Basins and Water Management Units

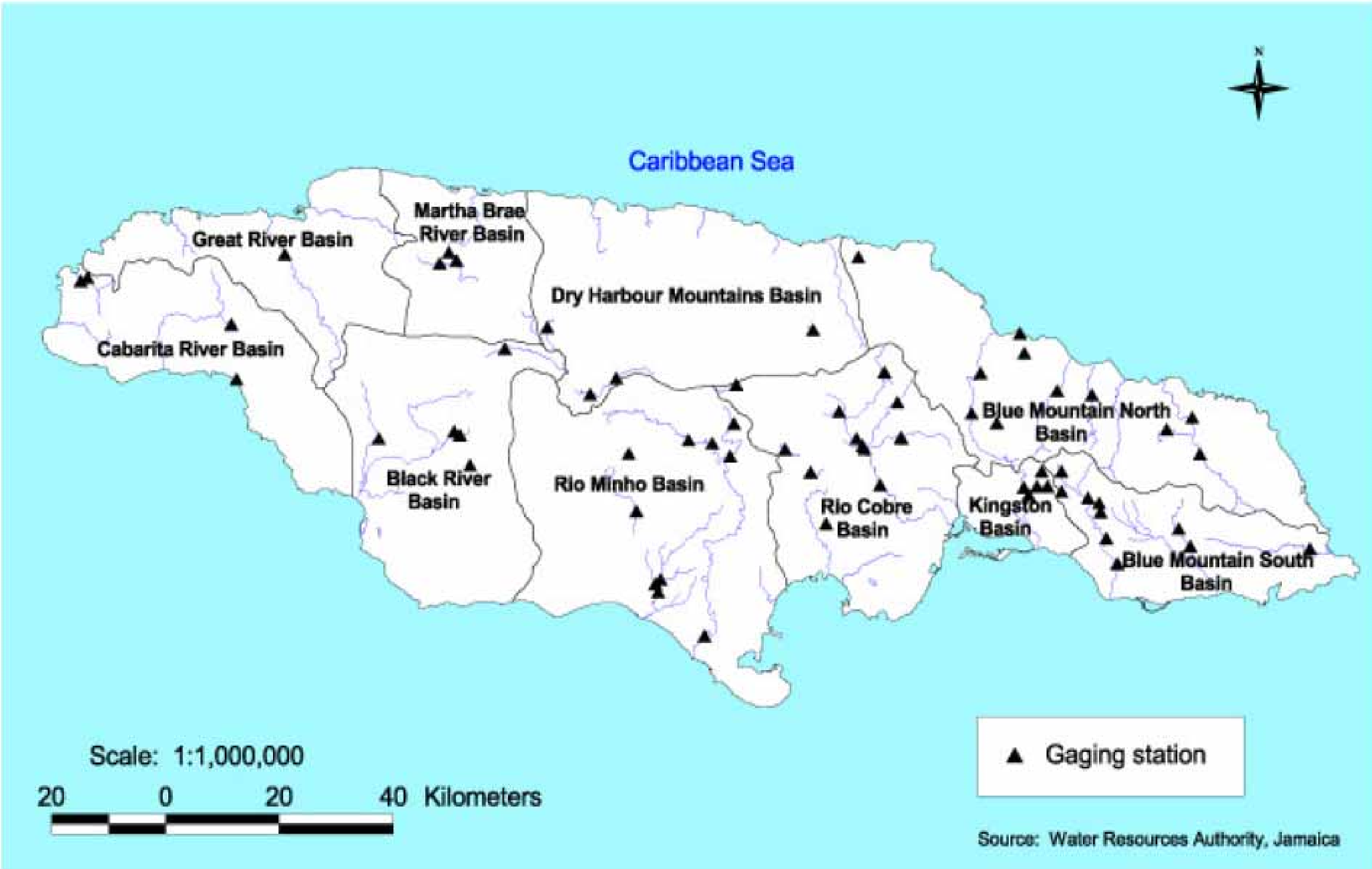


Table 4.11: Jamaica's Hydrological Basins and Water Management Units

Basin/Water Management Units	Area (km^2)	Annual Average Rainfall[1] (mm)	Annual Evapo-transpiration[2] (mm)
I – Blue Mountain South			
15-Plaintain Garden River	186.7	512	230
16-Morant River	375.7	805	431
17-Yallahs River	200.4	418	224
II – Kingston			
18-Hope River	241.4	302	162
III- Rio Cobre			
19-Rio Cobre	1256.5	1747	935
IV – Rio Minho			
20 – Rio Minho	789.3	1058	566
21 – Milk River	882.1	1364	730
22 – Gut-Alligator Hole River	142.9	224	120
V – Black River			
23 – Black River	1698.3	3318	1686
VI - Cabarita River			
24 – Deans Valley River	96.1	181	97
25 - Cabarita River	284.3	669	314
26 – New Savanna River	76.3	153	82
1 – S. Negril-Orange River	139.9	246	131
VII – Great River			
2 – Lucea River	253.2	569	256
3 – Great River	327.7	734	330
4 – Montego River	283.3	559	252
VIII – Martha Brae River			
5- Martha Brae River	622.2	1055	521
IX – Dry Harbour Mountains			
6 – Rio Bueno-White River	1563.1	2613	1398
X – Blue Mountains North			
7 – Rio Nuevo	111.1	209	94
8 – Oracabessa-Pagee River	169.5	305	137
9 – Wagwater River	315.1	641	288
10- Pencar-Buff Bay River	202.1	512	178
11 – Spanish River	121.6	449	157
12 – Swift River	97.2	344	103
13 – Rio Grande	302.4	1401	420
14 – Drivers River	210.9	692	208

Notes:
(1) 1951-1980 annual average rainfall
(2) Estimates from Water Resources Authority (2005)

4.3.2 Institutional Arrangements for the Management of Water Resources in Jamaica

The **Ministry of Water & Housing** is the focal point for activities in the water sector and has assumed the role of the main coordinating agency in the sector. It has responsibility for planning, development, and operations in the water sector. This responsibility is discharged through the Water Resources Authority (WRA), the National Water Commission (NWC), the National Meteorological Service (NMS), and the National Irrigation Commission (NIC).

<u>The Water Resources Authority</u>

The first organized programme for the systematic collection of stream flow data was initiated by the Water Resources Section of the Public Works Department in 1954. The Water Resources Division was established in 1965, when the Water Resources Section was transferred to the Geological Survey Department within the Ministry of Mining and Natural Resources. Between 1979 and 1984, the Water Resources Division was transferred to the Ministries of Local Government, Agriculture, and Public Utilities. In 1985, the Water Resources Division was merged into the Underground Water Authority (UWA). The mandate of the UWA was contained in the Underground Water Control Act (1959). The responsibility for the preparation of a national water resources development plan was assigned to the UWA in 1985. In 1993, the UWA was transferred to the Ministry of Water and Transport. The Water Resources Authority (WRA), formerly known as the Underground Water Authority, was established by the Water Resources Act of 1995 which repealed the Underground Water Control Act and the Water Act. The WRA therefore replaced the UWA as Jamaica's regulatory hydrological agency.

The WRA is responsible for the management, protection, and controlled allocation and use of Jamaica's surface and underground water resources. This responsibility will be achieved through the development and administration of a long term comprehensive Water Resources Development Master Plan for Jamaica. The latest update in this long term planning process is the 2005 National Water Resources Master Plan for Jamaica, which is currently updated as the 2008 Water resources Development Master Plan. This document seeks to enable rational decision making on current and future water use and allocation, providing economic and environmentally sound development options.

The Water Resources Act of 1995 requires that on matters of water resources development and quality, the WRA consult with, and provide technical advice and information to, and co-ordinate development with several other government agencies including the NWC, NIC, Ministry of Health, Commissioner of Mines, National Environment and Planning Agency, National Works Agency, Parish Councils, and others.

<u>The National Water Commission</u>

The National Water Commission (NWC) is responsible for urban water supply and is the largest provider of sewerage services. The NWC also has responsibility for many of the parish water systems and supplies 75 percent of the population with potable water. It is the principal implementing agency responsible for water resources development in the non-agricultural sector.

The NWC is a statutory body created in 1980 under the National Water Commission Act. Section 4(1) of the Act states that the functions of the NWC are as follows:

- Prepare and submit to the Minister from time to time proposals for the establishment of an efficient, co-ordinated and economical water supply system capable of meeting the needs for water throughout the Island;

- Prepare and submit for approval of the Minister details of schemes for the development of water resources and the supply of water in particular areas, and to carry out such schemes when they are approved;
- Keep under constant review the quality, reliability, and availability of water supply services as a whole and the rates charged for such services and advice the Minister on these and any other matters relating to water supplies in the Island which may be referred to the Commission by the Minister;
- Within the limits of its resources, provide and improve water supply services throughout the island.

The National Irrigation Commission

The National Irrigation Commission (NIC) is responsible for the development of agricultural water supply sources and for the operational aspects of the production and distribution. It was incorporated under the Companies Act in 1986. The primary goals of the NIC are to increase productivity and profitability in the agriculture sector and to achieve and maintain financial self-sustenance of the irrigation industry.

In 1998, the NIC was commissioned by the government to prepare a National Irrigation Development Plan (NIDP). The Master Plan of the NIDP assessed the current and potential state of the irrigated agricultural sector, the constraints and deficiencies facing the sector, and proposed policy, and the strategy and development plans to relieve the constraints and overcome the deficiencies within the sector. Approximately 25,000ha or 10% of cultivated lands in Jamaica are currently irrigated, while the NIDP estimated the potential irrigable areas to be over 90,000ha. The NIDP is scheduled for implementation over a 17-year period (until 2015). Over 120 projects were identified, of which 51 projects are proposed for implementation, with 27 of them recommended for implementation during the first five years of the plan. Details of recent projects covering the period September 2007 to January 2010 associated with implementation of the NIDP can be found at http://www.nicjamaica.com/NIDP_Achievements.htm.

National Meteorological Service

The Weather Branch of the National Meteorological Service (NMS) is concerned with the observation and forecasting of weather conditions over and around the island. It also maintains a continuous hurricane watch during the hurricane season and is responsible for the issuance of severe weather warnings. Data for forecasts are obtained locally from observation points at the surface, as well as from the radar station, and internationally through telecommunication links with regional and international centres and via stationary and polar orbiting satellites.

The Climate Branch is responsible for maintaining a current database of the climate of Jamaica and for using this data in informing productive sectors of the country. A Data Acquisition Section maintains an island wide network of rainfall and climatological stations; a Data Processing Section gathers, archives and analyses the climatological data with a view to monitoring and assessing the climate of the island; and an Applied Meteorology Section 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.

Other relevant organisations include:

Rural Water Supply Ltd: This company is an Agency of the Ministry of Transport and Works and focuses on developing water supply solutions for Jamaica's rural communities, both for public water supply as well as for local irrigation needs. It was established in 2005, with the merger of the Carib Engineering Company and the NWC's Rural Water Programme. Its aim is to ensure that all Jamaicans have access to piped water by 2010. The company seeks to include private sector and local community support, as it is these communities that will have responsibility for managing and maintaining the systems once they have been put in place by the company. The company also supervised the Rural Water Supply Project, funded by the Inter-American Development Bank (IDB) and the Government of Jamaica, which aimed to improve basic sanitary conditions by increasing the coverage of potable water and sanitation services in poor rural areas. The project was due for completion in February 2008.

National Environment & Planning Agency: The management of watershed protection is vested principally with the National Environment & Planning Agency (NEPA). NEPA 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 states the essential elements of a national watershed management initiative. It seeks to define opportunities for the people, for the government and nongovernment organizations, and for the international community to participate in the sustainable management and conservation of watersheds of Jamaica in the interest of water supply and bio-diversity. There are 12 guiding principles to the Policy, including:

- Long term watershed management;
- Design, planning and implementation of watershed management interventions;
- Special attention to people in watershed areas and their environment;
- Integral protection and production functions for land and water resources;
- Assessment of land used impacts and rehabilitation of damages;
- Compromise rather than confrontation and complementary rather than contradictory in resolving conflicts of interest;
- Co-operation among agencies and the public to manage watersheds effectively.

The Watershed Protection Act (1963) is the law governing watersheds and is administered by NEPA. The primary focus of the Act is the conservation of water resources by protecting land in or adjoining the watersheds. The Act is intended to ensure proper land use in vital watershed areas, reduce soil erosion, maintain optimum levels of ground water, and promote regular flows in waterways.

National Water Sector Policy

In January 1999, the Government of Jamaica, through the Ministry of Water, prepared and adopted a Water Sector Policy. This policy outlined the current situation and problems within the water sector, defined government objectives to address the issues, and set out the mode of implementation. To ensure that the policy was implemented effectively, the Government mandated the water agencies to prepare a Water Sector Strategy. This Strategy will indicate how the policies are to be implemented, and seeks to ensure an integrated and co-ordinated approach between all the agencies. The resulting Water Sector Policy, Strategy and Action Plan was promulgated in 2004[30] with its main water supply and sanitation objectives to ensure that all households have access to water by 2010, sewer all major towns

[30] http://www.wra.gov.jm/pdf/water_policy_2004.pdf

by 2020, as well as rehabilitate existing non-compliant facilities to achieve compliance with national environmental standards. The document also states that the objective with respect to water resources strategy is the management and regulation of the water resources of Jamaica with a view to its sustainable development and optimal use to satisfy all of the water supply needs of the island in an efficient, cost effective and timely manner. Strategies and an action plan are also presented for irrigated agriculture.

4.3.3 The Role of Water Resources in the Jamaican Economy

Water resources have a significant role in the Jamaican economy. Water is a valuable natural resource that supports important sectors including recreation & tourism, mining, food and beverage processing, irrigated agriculture and manufacturing. This significance is presented in Table 4.12, which shows the contribution of the various economic sectors to Jamaica's GDP and foreign earnings, as well as their annual use of water and regions of concentration (by Water Management Unit).

Table 4.12: Approximate Economic Contributions and Water Use, by Sectors (2005)

Sector	Direct Contribution to GDP	Foreign Exchange Earnings	Employment	Annual Water Use	Principal Locations
Units	**J$ billion**	**J$ billion**	**1000's**	**10^6 m^3/yr**	**WMU**
Manufacturing including food	125 (28%)	15 (8%)	215 (19%)	16 (1%)	18,19
Other services	120 (24%)	-	597 (53%)	10 (1%)	All
Hotels	106 (24%)	100 (55%)	75 (6.5%)	4 (0.3%)	4,5,6,18
Mining and Processing	60 (14%)	55 (31%)	6 (0.5%)	60 (5%)	6,19,20,21,23
Irrigated Agriculture	31 (7%)	10 (6%)	237 (21%)	439 (33%)	19,20,23
Residential	N/A	N/A	N/A	274 (21%)	18,19
Environment	N/A	N/A	N/A	510 (39%)	All

Source: Water Resources Authority (2005), Box 2.1

The major users of water are irrigated agriculture, residential water use, and the environment. There is no direct correlation between contribution to GDP, foreign earnings, and employment within each sector and the amount of water used. For example, manufacturing provides the highest contribution to GDP (28%) but uses only 1 percent of annual water use. Irrigated agriculture has the highest annual water use (33%), but only contributes 14 percent of total GDP.

Economic and other human activities in Jamaica have created a number of pollution problems. These include sewage effluent, as well as waste generated by sugar factories, alumina processing plants and rum distilleries. Improperly treated or disposed sewage has been found to contaminate parts of the Liguenua aquifer in the Kingston & St. Andrew region. Improvements in the treatment and disposal of sewage effluent should lead to an improved situation. Dunder from rum distilleries and sugar refineries has contaminated both surface and groundwater, leading to the occurrence of algal blooms, fish kills, and the loss of the affected streams for use by local communities. The red mud waste from alumina processing plants and its discharge into unlined or partially lined holding facilities has resulted in extensive contamination of both groundwater and surface water. Wells and springs have become contaminated and drinking water supplies threatened.

Human activities have also indirectly had a negative impact on water quality through over abstraction of groundwater sources, which has led to saline intrusion. This has occurred as frontal intrusion from the sea into coastal aquifers, or through saline upconing across aquifer boundaries.

Public Water Supply and Sewage

The vast majority of the public water supply in Jamaica is provided by the NWC. A summary of the NWC's water production supply and performance for 2002-06 is presented in Table 4.13. The decline in production in 2006 compared with 2005 was the result of drought conditions, which were more acute in eastern Jamaica. In some areas, production fell to 30 percent of capacity from July to September. In some locations, the situation was aggravated by plant outages.

Table 4.13: Summary of National Water Commission Water Supply Performance (2002-06)

Performance Indicator	2002	2003	2004	2005	2006*
Water Production (Million litres/yr)	276,835.5	293,382.0	280,308.0	296,454.1	294,384.0
Consumption (Million litres/yr)	95,094.0	96,329.0	94,729.0	94,415.7	95,318.0
Total number of connections	375,431	388,460	400,102	410,286	418,347
Total Revenue (J$M)	5257.1	5793.0	7293.1	8436.2	9297.4

*preliminary estimate
Source: Planning Institute of Jamaica, 2007

The NWC introduced a number of drought management measures to deal with the situation, including scheduled restrictions on supply, maximising abstractions from some sources and water trucking. Note that total metered consumption was slightly increased in 2006 compared with 2005, despite drought conditions.

As can be seen from Table 4.13, of the total water produced in 2006, 67.6 percent was non-revenue water, i.e., the difference between production and billed consumption. This includes loss as a result of theft, leakage, and underestimated consumption. Measures to reduce this are a priority for the NWC and most of the projects being undertaken by the NWC include activities to reduce these "losses". For example, almost 21,000 water meters were installed island-wide in 2006, following from a similar number installed in 2005. The increased number of connections in 2005and 2006, along with changes in the water tariff, increased revenues by J$861.2M between 2005 and 2006.

Irrigated Agriculture

Irrigated agriculture accounts for approximately 25,360 ha (9.3% of cultivated lands), while representing around 55 percent of Jamaica's total water usage (excluding environmental needs). This high demand reflects low irrigation efficiencies, estimated to be around 40 percent, although this varies dependent upon method of irrigation, management of irrigation system, investment, and other factors. There is scope to improve irrigation efficiencies by moving away from surface furrow methods, which in the mid 1990s accounted for 80 percent of the systems supplied by the NIC and 70 percent of privately operated systems including aquaculture, to more efficient overhead sprinkler and drip irrigation systems.

However, improvement in irrigation efficiencies may not lead to a reduction on total water withdrawals, as any water savings could be used to bring new areas under irrigation and therefore leave the overall consumption of water resources for this sector unchanged. The NIC (NIC, 2004) estimates that irrigated lands will double by around 2025. Improved efficiencies may also have other consequences, where inefficient irrigation is a significant source of aquifer recharge, e.g., for the alluvial aquifers of the Rio Cobre and Rio Minho, and where investment in new irrigation methods could have negative impacts on the water balances of coastal aquifers.

Aquaculture is also an important user of water, and requires high quality water for the rearing of tilapia.

Industry

Compared with irrigated agriculture, other sectors of the Jamaican economy are smaller users of water. However, certain industrial activities are concentrated in specific parts of the island and therefore have a greater impact on local water use – such as the bauxite-alumina operations in central Jamaica.

Tourism is an important part of the Jamaican economy and the highest contributor to foreign earnings. The hotel sector has one of the lowest water demands, but its requirements are high, given the importance of a reliable and safe water supply to its customers. Linked with this is the importance of water based recreational activities. As indicated in Table 4.12, meeting environmental requirements is a significant proportion of Jamaica's overall annual water use. This has benefits not just in conservation of the aquatic environment and wider benefits to Jamaican society, but also to maintain the attractiveness of Jamaica's water based attractions to the tourism sector.

The Environment

As noted above, there are clear ecological and economic reasons for explicitly including environmental flow requirements within any assessment of the economic role of water resources in the Jamaican economy. Aquatic ecosystems provide a range of benefits, e.g., water supplies and recreational sites, as well as "natural" water treatment in streams and wetlands. Reducing water flows in both river and groundwater ecosystems will have a negative impact on the flora and fauna of these ecosystems but also on the human communities that depend on these systems.

The estimates of environmental flow needs presented in Table 4.12 are based on those presented in Water Resources Authority (2005). These include estimates of required groundwater submarine discharges to the sea to prevent saline intrusion as well as estimates of minimum stream flow requirements to maintain aquatic ecology. However, it is recognised that especially for the stream flow requirements further work is needed to refine the estimates given.

4.3.4 Vulnerabilities of Jamaican Water Resources to Current Climate

Table 4.14 presents the estimated annual water resources situation for each of Jamaica's basins for 1995. The current 1990 Water Resources Master Development Master Plan is in the process of final update and revision for publication in 2008, and therefore the values presented in this table are subject to review and further detail down to the MWU level.

Table 4.14: Annual Water Resources Resource Demand Balance (10^6 m^3/yr), by Water Management Unit (1995)

Basin	Potentially Available Water Resources	Imports	1995 Demands	Surplus/ Deficit	Surplus or Deficit/ Resource
I – Blue Mountain South	165	0	57	108	65%
II – Kingston	46	67	90	23	20%
III – Rio Cobre	415	0	397	18	4%
IV – Rio Minho	466	9	311	164	35%
V – Black River	674	1	60	615	91%
VI – Cabarita River	451	0	26	425	94%
VII – Great River	380	10	21	369	95%
VIII – Martha Brae	170	0	31	139	82%
IX – Dry Harbour Mountains	719	0	19	700	97%
X – Blue Mountain North	611	1	46	566	92%

Source: Army Corp Engineers, 2001

The estimates of potentially available water resources are based on annual average conditions under current climate. The estimates are based on the following water balance equations and calculations for groundwater and surface water contributions respectively:

Aquifer Safe Yield = (Precipitation – Evapotranspiration) – Surface Runoff – GW Return Flow
River Safe Yield = Q90 low flow (flow that occurs at least 90% of the time)
Potentially Available Resources = Aquifer + River Safe Yields

Demands have been estimated for agriculture, domestic use, industry and tourism, as well as exports to neighbouring catchments. For Kingston and the Rio Cobre and Rio Minho basins, additional groundwater recharge was estimated to be from reservoir leakage and irrigation respectively. Kingston, the Rio Minho, Black River, Great River and Blue Mountains North also receive imports from neighbouring basins. The main recipient is Kingston, which receives water from both the Blue Mountains South and the Rio Cobre.

As can be seen in Table 4.14, three Basins show clear evidence of water stress, as measured by the ratio of surplus or deficit to available resource expressed as a percentage. These are Rio Cobre at 4 percent, Kingston at 20 percent and Rio Minho at 35 percent. The next highest value is 65 percent for the Blue Mountain South Basin. This relates directly to the export to Kingston from this basin. For the remaining basins, this value ranges from 82 percent to 97 percent.

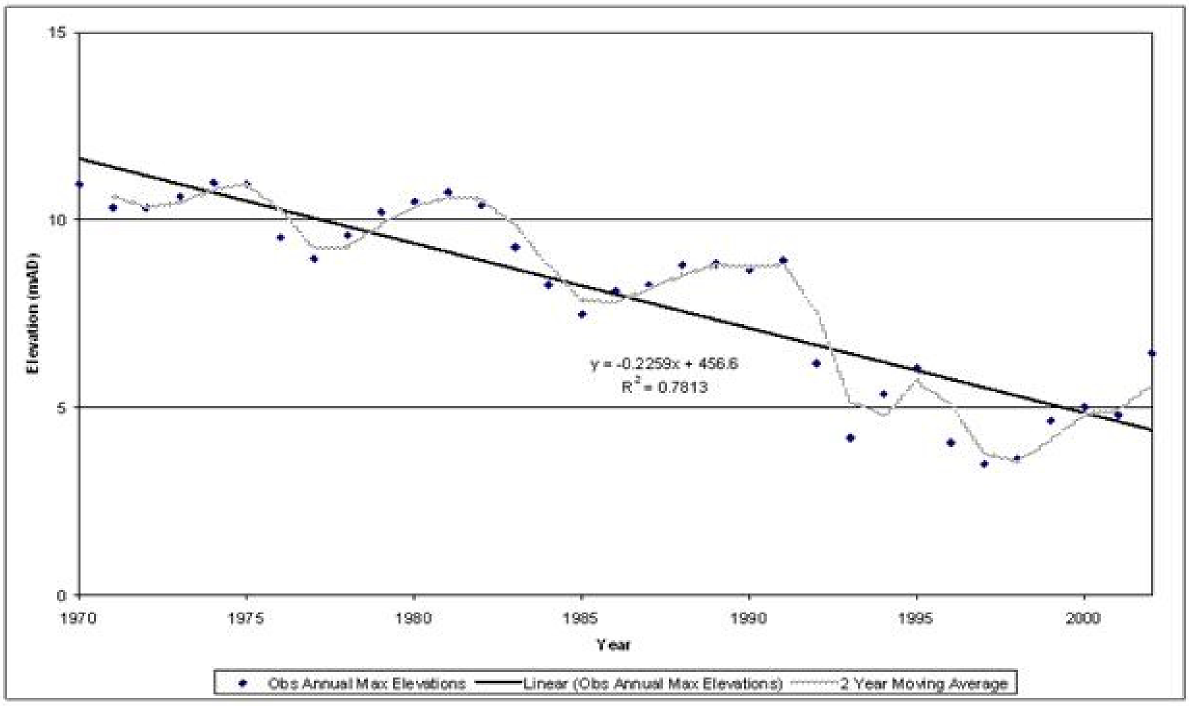
In the case of the Kingston Basin, demands are driven by municipal and industrial needs, given that Kingston, the capital of Jamaica, is located within this basin. In contrast, for the Rio Cobre and Rio Minho, it is irrigation needs that are the greater and which drive demand for water in these basins. Thus, even under average climatic conditions, a significant proportion of the Jamaican population and important parts of the Jamaican economy are vulnerable to the risk of water supply shortfalls.

The analysis presented in Table 4.14 is limited to a comparison of water resources availability and demand only. It does not factor in water delivery/engineering systems, their capacities or reliabilities, and therefore the results only present a preliminary analysis of basin water resources vulnerability. A further refinement of this analysis would include assessments of engineering capacities of intakes / wells / pipelines / treatment plants / service reservoirs for each water supply system.

It is also the case that the analysis presented in Table 4.14 is based on annual average conditions. The performance of water delivery systems under a range of climatic and drought conditions is also needed in order to assess levels of service of supply under existing climate and how these levels of service compare with the water providers' own target levels of service. Such an approach requires the adoption of more complex approaches and methods of analysis, the use of enhanced water resources modelling tools as well as the time series data and other data on the engineering aspects of the water delivery systems of interest.

Despite the preliminary nature of the results presented in Table 4.14, evidence that basins are already under stress with respect to their water resources can be seen in the analysis of hydrometric and hydro-geological time series data. For example, Figure 4.9 presents a time series analysis of groundwater elevations from an important alluvial aquifer in southeast St Catherine within the Rio Cobre Basin. This aquifer was used for irrigation through to the 1980s, and from the 1990s switched to be predominantly used for public water supply to the "new town" development of Greater Portmore.

Figure 4.8: Lime Tree#2 in SE St Catherine Trend Analysis: Observed Annual Maximum Series Groundwater Elevations (1970 to 2002)



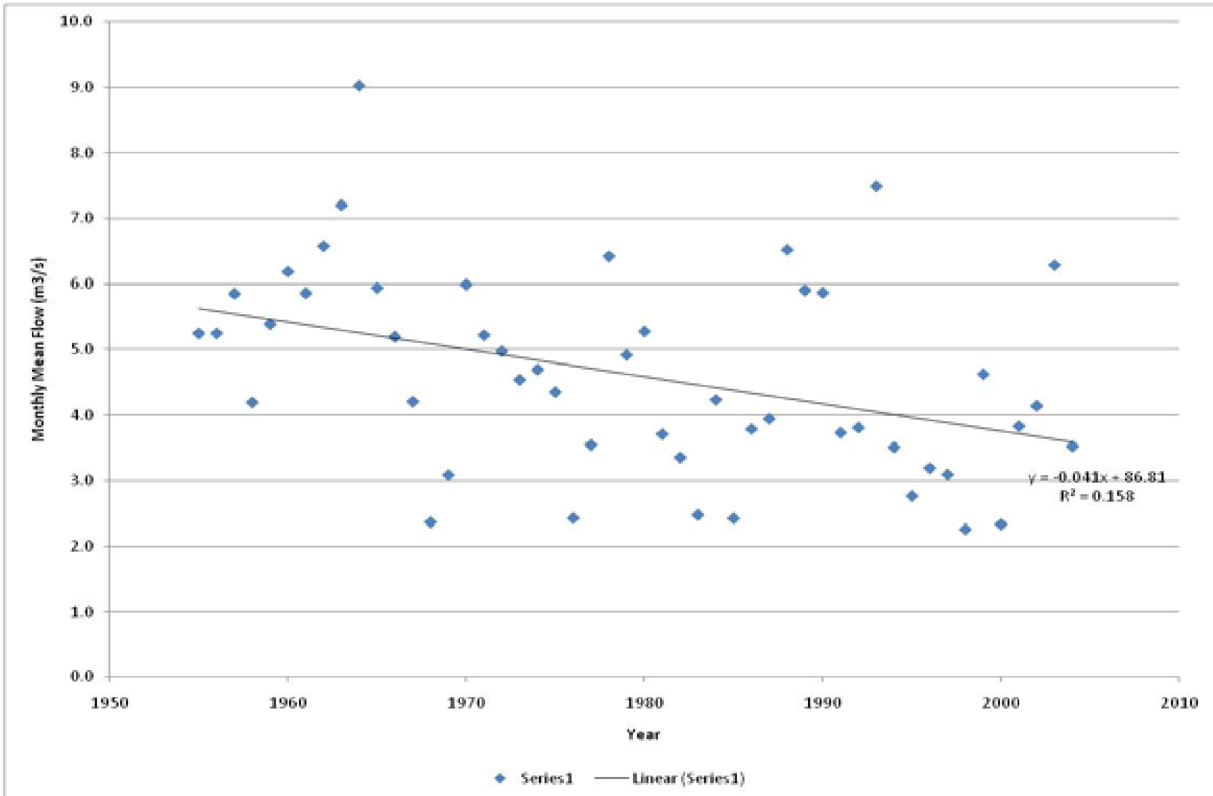
Data Source: Water Resources Authority

Groundwater elevations at this location are influenced by nearby production wells. To reduce these local influences, only annual maximum elevations have been plotted. These annual maximum values give an indication of what is happening regionally to groundwater elevations and thus storage within the aquifer. As can be seen, there is both a cyclical pattern as well as a long term trend of decline elevations.

The annual maximum elevation at the start of the 1970s was above 10mAD, but had declined to around 5mAD by 2000. During this 30-year period, the annual maximum series shows increases in elevation during wetter periods, followed by declines in elevation during average and drier periods. Nevertheless, the key feature is the long term decline in groundwater elevations, indicating that abstractions from the aquifer are taking place at a greater rate than the long term recharge, with the result that groundwater storage is declining, as seen in the groundwater elevations. This is a coastal aquifer, and therefore is at increasing risk of saline frontal intrusion with the continuation of such trends into the future.

Further evidence that the Rio Cobre Basin is under stress can be seen in the time series of annual (estimated) minimum monthly flows for the Rio Cobre at Bog Walk presented in Figure 4.10. This plot shows annual minimum monthly stream flows from 1954 to 2004, indicating a decline in these flows from a mean value of 5.5 m^3/s in the 1950s to 3.5 m^3/s in the 2000s. No evidence of similar declines was found in the neighbouring Rio Minho Basin nor was trends found in the monthly rainfall record for the Rio Cobre. Therefore, it is more than likely that increased abstractions upstream of Bog Walk are having an impact on stream flows. This presents further evidence for the stressed and vulnerable nature of water resources under current conditions, and raises issues related to water resources monitoring, management, and control within the Rio Cobre and throughout Jamaica.

Figure 4.10: Rio Cobre at Bog Walk Estimated Annual Minimum Monthly Stream-Flows (1954to 2004)



Data source: Water Resources Authority

Public Water Supply

Issues of low levels of service of water supply to the Jamaican population are not just limited to the most vulnerable WMUs discussed earlier. There are a large number of smaller communities that rely on springs and run-of-river sources for their water supply and which, during periods of drought, suffer from shortfalls in supply and reduced reliability. In many cases, these problems are related to a lack of surface water storage in these localities, where source yields are driven by drought flows, and reservoir storage is not available to provide water resources during times of drought – for example, communities in Clarendon, St. Mary, and St. Thomas.

In parallel with the reduced availability of water resources during drought periods, there are also problems resulting from lack on investment in water supply infrastructure. This is in terms of both development of new infrastructure as well as maintenance of existing systems. The NWC and the Rural Water Supply Company have a number of projects and initiatives under development and at implementation to improve performance and either maintain or enhance the level of service offered to customers, within the constraints of the existing climate.

The public water supply system is also vulnerable to the passing of tropical storms and hurricanes. Table 4.15 summarises the estimated costs to the NWC from tropical storms and heavy rainfall periods since 2002. Direct costs are those related to direct damages to plant and equipment, while indirect damages are related to loss of income.

Table 4.15: Estimated Losses to NWC Resulting from Recent Tropical Storms / Hurricanes (2002-05)

Tropical Storm/Hurricane	Direct Losses (J$M)	Indirect Losses (J$M)
May 2002 storms	54.805	30
Hurricane Ivan (2004)	90	488
Hurricanes Dennis & Emily (2005)	Total Losses = 400	
Hurricane Wilma (2005)	47.4	N/A

Sources: Economic Commission for Latin America and the Caribbean (2002), Economic Commission for Latin America and the Caribbean (ECLAC) et al 2004, Planning Institute of Jamaica (2005a), Planning Institute of Jamaica (2005b) respectively

Problems commonly encountered include silting of settling tanks and filters, damage to pumps and electrical equipment, scouring of pipelines, blocked canals, landslide affecting pipelines, and flooded well fields and stations.

Where Jamaica Public Service brings in partial or national shut downs of the power grid, then only those NWC systems that have their own stand-by generators or those which are gravity driven are the most likely to stay operational with the passing of a tropical storm or hurricane. Water quality in many of the distribution systems can also compromised, with a resultant threat to public health, as well as having impacts on household budgets where additional expenditure on bottled drinking water may be required.

<u>Irrigated Agriculture</u>

Irrigation systems operated by the NIC are also vulnerable to damage by tropical storms and hurricanes. For example, NIC infrastructure was affected by both Hurricanes Dennis and Emily to the tune of $30.4 million, such as flooding to pumping stations; damage to access roads and structures; deposition of silt and debris on open canals; dislocation to sections of pipeline; etc (PIOJ, 2005a).

Industry

Productive sectors of the economy also suffer from the loss of water supply, either under drought conditions, which are more longer term in nature, or due to interruption in supply due to tropical storms/hurricanes. The latter are shorter in duration and may only last 1-2 weeks. For example, 13 days after the passage of Hurricane Emily, approximately 380 NWC water systems serving about 93 percent of customers were operating (PIOJ, 2005).

The Aquatic Environment

Impacts of the existing climate and climatic variability on Jamaica's aquatic environment reflect both the occurrence of climate events such as tropical storms and hurricanes and droughts as well as human activities that increase the sensitivity of the environment and thus vulnerability of the environment and people to these climatic events.

Examples include inadequate settlement patterns and land use practices that have greatly altered the natural rainfall-runoff relationships so that hydrographs tend to rise more quickly and flood flows are more frequent. Accelerated erosion accompanies the rapid runoff as natural protective resources become increasingly degraded. Settlement also occurs in hazard prone solution basins and floodways which are often compromised in their ability to discharge floodwaters because of blocked sinkholes or heavily silted channels. Examples of these poor land use and settlement activities are presented in Figure 4.11. Countering these practices and activities is one of the main aims of the GEF-funded *Integrating Watershed and Coastal Areas Management* (IWCAM) project, which ran at the implementation stage from 2005 to 2010 and is also seen as being important to the Forestry Department through the implementation of the National Forestry Plan.

Figure 4.11: Examples of Poor Landuse Practice and Settlement Activities in Jamaica

The occurrence of tropical storms and hurricanes can have a range of impacts on the aquatic environment. With the factors referred to above, these impacts are directly felt by sectors of the Jamaican population. Examples of these are summarised in Table 4.16 and illustrated in Figure 4.12.

Impacts of the existing climate and climatic variability on Jamaica's aquatic environment reflect both the occurrence of climate events such as tropical storms and hurricanes and droughts as well as human activities that increase the sensitivity of the environment and thus vulnerability of the environment and people to these climatic events.

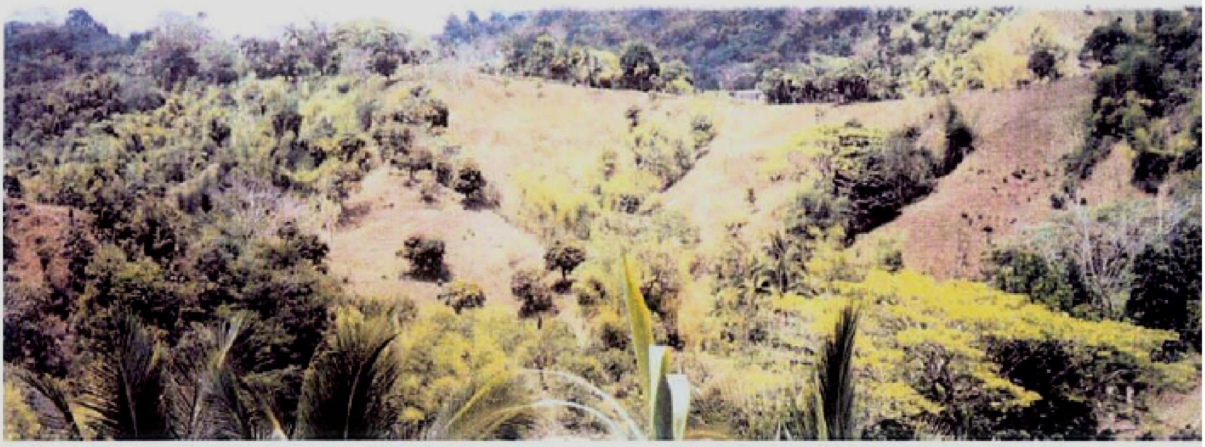
Table 4.16: Examples of Impacts from Tropical Storms / Hurricanes on the Aquatic Environment

Attribute	Impact	Examples
Rivers/ surface water	• Changes in river course • Sediment erosion and deposition	During Hurricane Ivan, river bank erosion and collapse was particularly marked in the Hope River Valley in Kingston where extensive settlements (legal and squatter) occupy the banks and terraces of the river in northeastern St Andrew
Groundwater	• Groundwater flooding	Widespread groundwater flooding, including properties, at Content in Manchester in 2002
Water quality	• Increased turbidity • Pollution	Destruction of sewage treatment facilities at Yallahs following Hurricanes Dennis & Emily, with raw sewage entering Yallahs River.

Figure 4.12: Examples of Tropical Storm / Hurricane Impacts on the Jamaican Aquatic Environment

Denudation of Hill Slope Valley in Buff Bay

Source:Treesfor Tomorrow Project (2004)



Clearance followed by burning on steep slopes in the Martha Brae Watershed has accelerated the gully formation

Source:Treesfor Tomorrow Project (2002)

Silt plume near the mouth of the Wag Water River moving in a north westerly direction towards Robins Bay following Hurricanes Dennis & Emily.

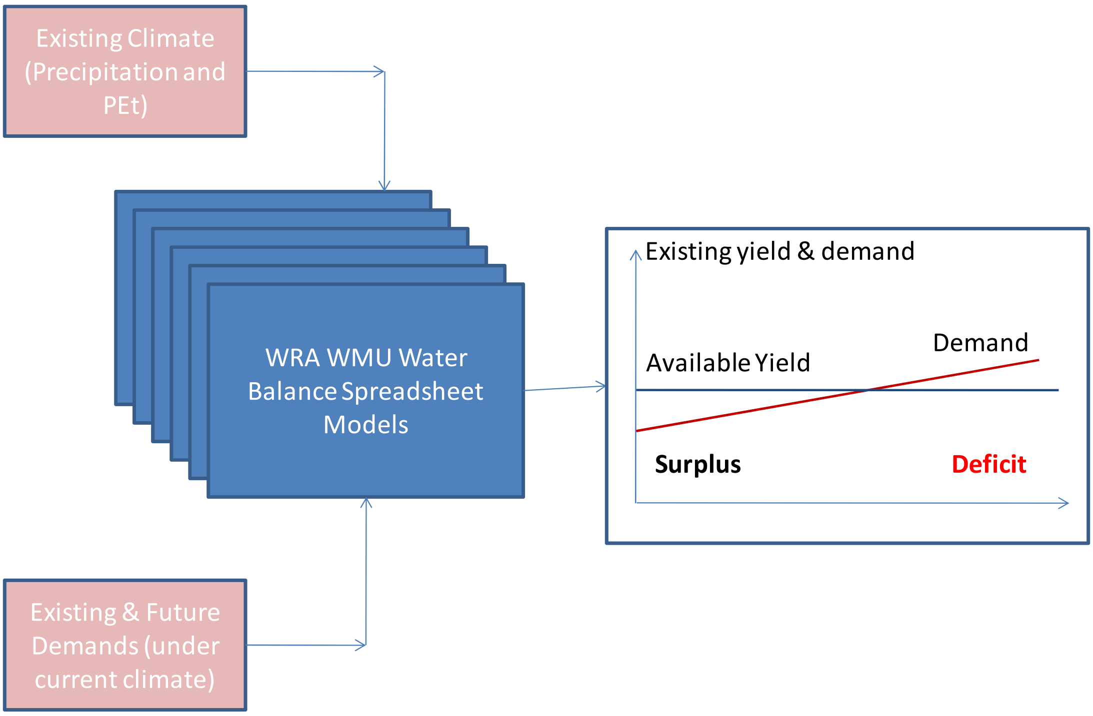
Untreated Sewage effluent flowing into Yallahs River from damaged pond following Hurricanes Dennis & Emily.

4.3.5 Analysis Of Future Climate Risks For Jamaican Water Resources

The results of analysis looking at 1995 water resources availability versus demand situation on a basin by basin basis was presented in Table 4.14. The approach adopted in this relatively simple analysis forms the basis of assessing the potential impact of climate change on these balances and from there looking at potential demand side solutions to address any increase in deficits that can be attributed to climate change. The proposed methodology is outlined in Figures 4.13a to 4.13c.

Figure 4.13a outlines the first stage in the analysis, which uses the existing basin (and for more detail, MWU) spreadsheet models to assess the supply demand situation under existing climate with existing and future demand estimates. This allows the tracking of the change in the supply demand situation from, as an example, a situation of surplus to deficit as projected demands increase in the future.

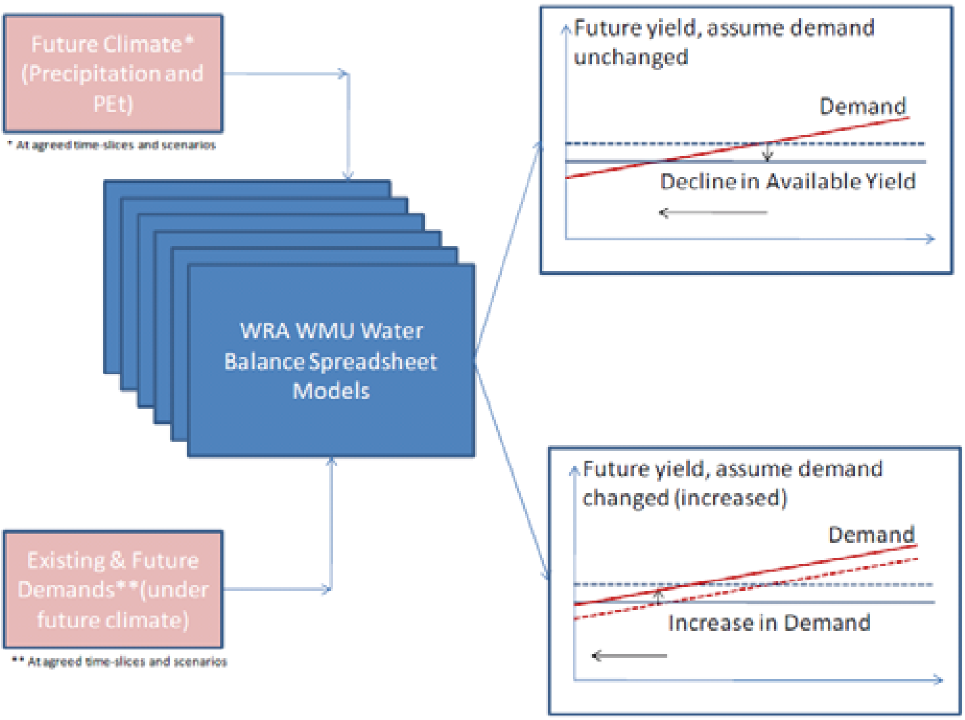
Figure 4.13a: Assessment of Existing Climate Supply-Demand Balances



In Figure 4.13b, the same Basin/WMU water balance spreadsheets are taken forward, but the inputs are future climate estimates (expressed as % changes in precipitation), for the selected time periods (2030, 2050, or 2080, for example) and scenario of interest, with associated estimates of water demand either assumed unchanged or revised across the MWU and sectors of interest for the same time slices and under the same scenarios. Note that for these estimates of scenario changes in water resources availability, it is assumed that the internal relationships between, for example, rainfall and evaporation, as well as net rainfall and surface water runoff remain unchanged.

Where it is assumed demands are unchanged under future climate, then the impact of the analysis is likely to lead to a reduction in potentially available water resources, and the bringing forward of the “tipping point” of moving from a situation of surplus to deficit. Where it is additionally estimated that demands are likely to increase under this scenario, then this tipping point will move even further forward.

Figure 4.13b: Assessment of Future Climate Supply-Demand Balances



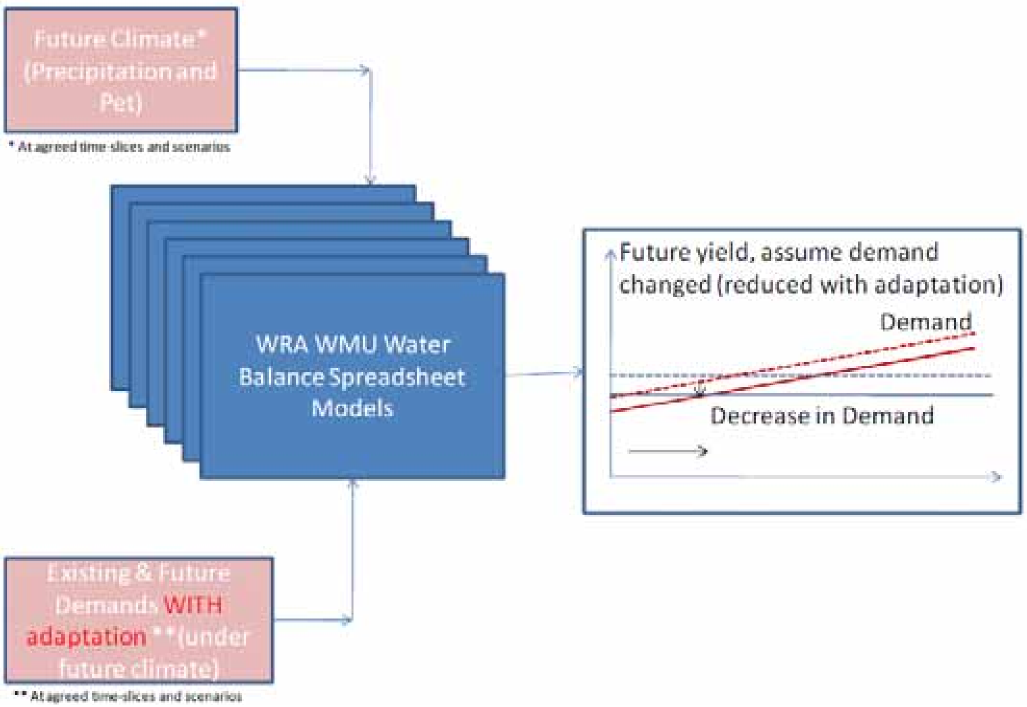
Note that at this stage, no adaptation measures are included. This is the next stage in the analysis, as represented by Figure 4.13c. However, given that the balances are based o potentially available water resources and do not include the engineering interventions and assets that bring water from the sources to the users, only demand side measures at the WMU scale can be explored here. This could include looking at the reduction in demands from improved irrigation efficiency, both in delivery as well as application on fields, and their impact on reducing deficits and MWU balances.

However, further development on the supply options could be explored in this framework. For example, it is possible to look in more detail at water supply zones within each MWU and assess their (engineering) performance against existing demand. In this way, it would be possible to include supply side factors within the supply-demand balance, taking these forward to look at the balances under climate change, and in doing so provide a framework to introduce possible engineering and other improvements to address reduced surplus or deficits under climate change scenarios.

This approach only focuses on climate change and changes to annual average conditions. Impacts of changes to climatic variability cannot be assessed using this approach. For example, investigating the impacts of changes to drought frequency and severity on water resources availability and delivery to users can only be discussed in a qualitative manner at this time until more complex modelling approaches are developed.

Nevertheless, with knowledge of the locations of existing water supply schemes reliant on springs or run-of-river sources, some preliminary assessment of those communities still most at risk from both existing and future climatic variability can be made, and measures developed to address and reduce these risks.

Figure 4.13c: Assessment of Future Climate with Adaptation Supply-Demand Balances



<u>WMU Water Availability Demand Balances under Climate Change</u>

The methodology presented above is based on the availability of MWU water balance spreadsheet models associated with the 2008 Water Resources Development Master Plan Update. These are expected to provide a much more detailed basis and analysis of the supply demand situation than currently available from the 1990 Water Resources Development Master Plan. Therefore, the results presented here are at the basin scale and are based on data presented in the 1990 Master Plan as well as US Army Corps of Engineers (2001). As noted above, in developing these water supply-demand balances, derived relationships from the 10 basins from the 1990 Master Plan between rainfall and evapo-transpiration, and net rainfall and annual runoff and 90 percentile flows are assumed to be unchanged in developing the water supply estimates of potentially available water resources.

Using this approach, water resource availability versus demand estimates for the three critical basins of Kingston, Rio Cobre, and Rio Minho are presented in Table 4.17 for the 2015, 2030 and 2050. Note that demand estimates for 2015 have been assumed to apply to 2030 and2050, and that imports into the basins are also assumed to remain unchanged through these periods. Estimated percentage changes in rainfall from the pooled global climate modelling results were used, giving reductions in annual average rainfall of 0.8 percent by 2015, 2.2 percent by 2030 and 5.9 percent by 2050.

The results presented in Table 4.17 show the Kingston Basin moving from a surplus of 39.0 Mm^3/yr for the 1990s to a small deficit of -2.3 Mm^3/yr by 2015. Beyond this period it is difficult to estimate, as demands are assumed unchanged for 2030 and 2050, as are the imports to the basin. For the Rio Cobre, there is an estimated surplus in 1990 of 130.3 Mm^3/yr becoming a deficit between 1995 and 2015, with an estimated magnitude of 32.5 Mm^3/yr by 2050. In the case of the Rio Minho, the trend is somewhat different, as estimates for the 1995 situation show an increasing surplus, while estimates for 2015 and beyond indicate the presence of an increasing deficit. This indicates some inconsistencies in the estimates for this basin between the two sources used to derive this table.

Table 4.17: Estimated Water Resources Availability – Demand Balances for the Kingston, Rio Cobre and Rio Minho Basins (Mm³/yr)

Basin		Period				
		1990	1995	2015	2030	2050
Kingston	Total Available Resources	46.0	46.0	45.7	45.2	43.8
	Import	67.0	67.0	67.0	67.0	67.0
	Demand	74.0	90.0	115	115	115
	Balance	39.0	23.0	-2.3	-2.8	-4.2
Rio Cobre	Total Available Resources	435.3	435.3	433.0	428.8	417.5
	Import	0.0	0.0	0.0	0.0	0.0
	Demand	305	397	450	450	450
	Balance	130.3	38.3	-17.0	-21.2	-32.5
Rio Minho	Total Available Resources	486.3	486.3	483.0	477.0	460.8
	Import	9.0	9.0	9.0	9.0	9.0
	Demand	368	311	632	632	632
	Balance	127.3	184.3	-140.0	-146.0	-162.2

Reference: Underground Water Authority (1990), US Army Corp Engineers (2001)

For the Kingston Basin, the results perhaps show an overly optimistic situation, given the assumed continuing supply of water from other basins. One of the main sources of this import is the Rio Cobre basin, which as shown, is projected to be moving into a deficit situation which will result in increasing competition for water resources. Therefore, it is important that the Kingston Basin seeks to reduce its reliance on these existing imports and either develop new resources /imports from neighbouring basins or introduce significant efforts to address the projected growing demands.

This includes measures within the domestic, industrial and commercial sectors to reduce per capita water use, as well as taking a proactive stance to reduce unaccounted for water (a major component of which is leakage). As commented earlier, the NWC is adopting such measures island-wide with a metering programme, as well as the introduction of measures to address unaccounted for water.

For the Rio Cobre, the demands are mainly agricultural. At the time these demand estimates were prepared, the area under sugar cane cultivation was significantly larger, and it is very likely that with both this decline and the recent introduction of more efficient irrigation methods that the demand estimates for this basin will be very much reduced. However, it is important to note that the introduction of more efficient irrigation methods may lead to a reduction in irrigation based recharge and therefore a reduction in total available resources. Although, demands are mainly from agriculture, non-agricultural demands are likely to increase especially in the southern part of the basin associated with new highway development and the zoning of land either side of the highway for development. For the Rio Minho, the situation is comparable, with agricultural remaining the main sector for water demands, but with an increasing urban public water supply demand from new growth.

Within the context of the Water Resources Development Master Plan Update of 2008, this analysis will require revision on a basin and WMU scale. With the expected advances in both resource and demand estimates, this will allow a more thorough basis on which to develop, investigate and assess the feasibility of adopting WMU wide demand side measures to counter both existing and projected deficits under climate change. This will support the required analysis that is also needed to investigate supply side measures.

4.3.6 Impacts on Water Resources from Increased Climate Variability

As well as the likely changes to average climatic conditions by 2050, the projections also indicate increased climatic variability. Some of the features of this increased variability by 2050 include:

- Length of the rainy season – down by 7-8 percent;
- Length of the dry season – up by 6-8 percent;
- Increased frequency of intense rains –projected to increase 20 percent;
- Strongest hurricanes more intense, increasing disaster losses.

Thus, the climate projections are indicating a general increase in the frequency of extreme events such as droughts, floods and increased intensity of heavy rain events.

This increased climate variability is likely to have a number of impacts on water supply:

1. *Increasing length of dry season will increase the vulnerability of those communities who are supplied by single spring or river sources*. Lower annual average rainfall linked with a longer dry season is likely to reduce the safe yield from these sources.

2. *Increased frequency of intense rains will have an impact on water supply, as these rains are likely to result in watershed flows associated with high sediment loads*. Increased sediment loads will place increased requirements on water treatment facilities to treat water to an adequate standard before entering supply. Therefore, upgrading of treatment facilities may be required, as well as the need to introduce higher cost treatment processes (capital investment with higher operating costs).

3. *Changes in the climate regime are likely to impact the hydrological regimes across basins, including impacts on groundwater recharge*. On a long term annual average basis, decreased rainfall with increased temperatures and evapotranspiration will reduce potential groundwater recharge. It is also the case that if the rainfall that does occur is concentrated in a smaller number of events, then a greater proportion of this may not be available for recharge, but will be taken up to address increased soil moisture deficits, as well as leading to the greater proportion of direct runoff. Further watershed based hydrological studies are required to assess the impacts of climate change on Jamaican basin hydrological / hydrogeological regimes and water balances.

4. *The projected increased intensity of hurricanes will increase the potential losses of infrastructure with the water sector, as well as revenue after the event and during the recovery period.* There are also wider watershed and catchment management issues associated with increased climate variability. As noted above, increased frequency of more intense rainfall events has an impact on sediment erosion, movement and transport within basin river systems. Poor land use and agricultural practices can increase the vulnerability of watershed slopes to soil erosion and sediment transport.

Therefore, it is important that the work within the IWCAM project is developed to identify best management practices in these areas and methods and models of transfer of these best practices to other basins within Jamaica.

Vulnerability to Sea Level Rise

Coastal aquifers remain a significant source of water supply for both the agricultural and non-agricultural sectors, especially in the Rio Cobre and Rio Minho Basins. Groundwater was in the past an important source of water supply in the Kingston Basin, but over abstraction resulted in problems of saline intrusion. Water quality problems were compounded in the Kingston Basin by sewage contamination of the aquifers.

The projected increases in sea level within the Caribbean in general and around the coasts of Jamaica in particular varies from 0.17m to 0.24m by 2050 (IPCC, 2007). Others (Rahmstorf, 2007) have given higher magnitudes of 0.25m to 0.36m against 1990 sea level. Given the coastal location of many of Jamaica's wells used for agriculture, public water supply and industry, such increases in sea level increase the potential risk of saline intrusion into the coastal aquifers. There is a past history of poor water resources management in these coastal aquifers, with the abandonment of wells for public water supply, for example in the alluvial aquifer of the lower Rio Cobre basin.

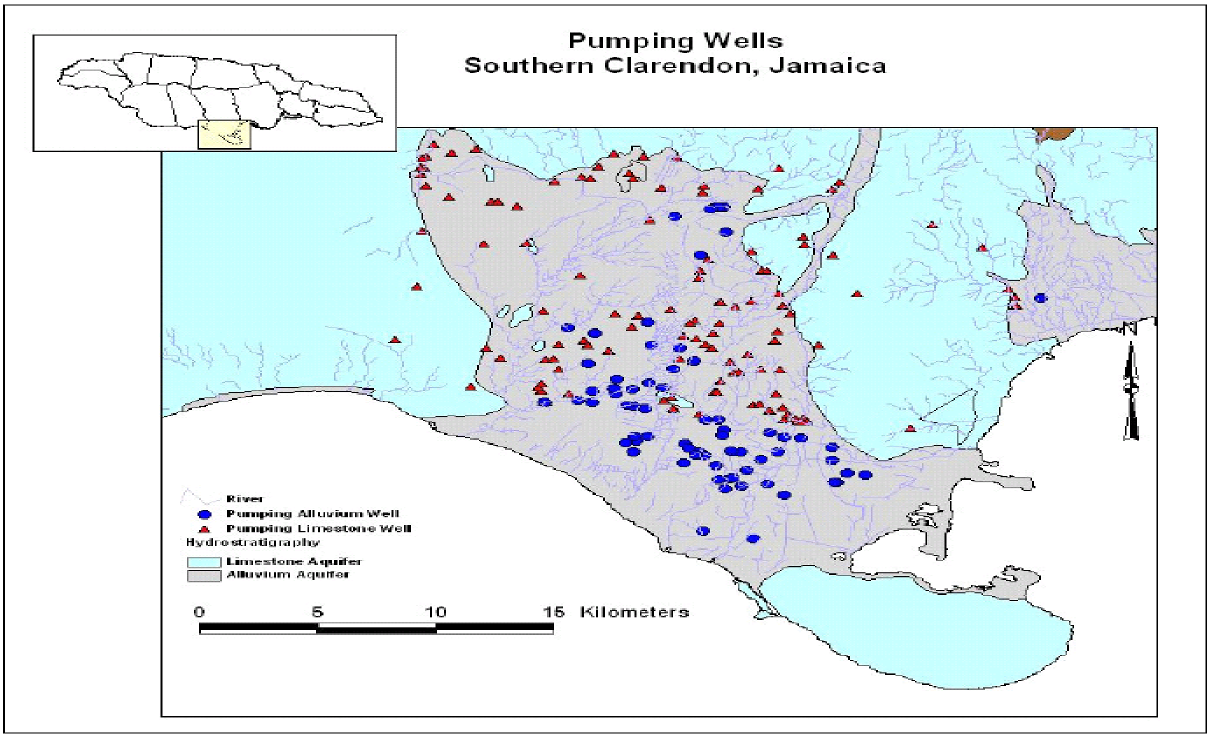
The Mainstreaming Adaptation to Climate Change Programme (MACC) has provided funding for the implementation of a pilot vulnerability and capacity assessment project in the water sector in Jamaica. The Vere Plains of southern Clarendon was selected as the study area (Haiduk, pers. comm. 2008). The objectives of the study are to identify:

1. How a predicted sea level rise of 0.5m to 1m would move the saline front inland and change groundwater quality;
2. The response strategies including policy intervention that would be required to minimize effect if any; and
3. The requirements for monitoring rainfall intensity in south Clarendon.

The project area is illustrated in Figure 4.14 and shows the locations of pumping wells in both the limestone and alluvial aquifers within the plains. Within the project area, wells tapping the southern section of the limestone aquifer have been abandoned due to high salinity, and there remain wells within this part of the project area with salinity levels exceeding the WHO aesthetic guidelines concentrations for sodium and chloride.

Work on this project had stalled due to technical constraints, but was to be completed by the end of 2008. The delay was unfortunate, as the findings of this project would have provided significant and useful information on the risks and vulnerability to groundwater resources in Jamaica from sea level rise and brought forward technical and policy recommendations to develop adaptation strategies and programmes to address, manage, and reduce vulnerability for inclusion within this report.

Figure 4.14: MACC Vulnerability and Capacity Assessment Project Area



(Source: Haiduk, pers. comm. 2008)

Impacts on river low flows from climate change and increased climate variability can be inferred in a preliminary quantitative and qualitative manner. With respect to impacts from climate change and mean climatic conditions, some preliminary results are presented in Table 4.18 looking at potential future changes to the 90 percentile low flow (Q90), expressed as a percentage of existing mean annual flow for each basin. These results are based on the basin water supply-demand balance calculations that were summarized in Table 4.14. Here the same internal relationships between net rainfall and Q90 were applied to look at estimated changes in Q90 from the existing values through to 2015, 2030 and 2050 under the same changes in annual average rainfall from the climate modelling studies, and as stated earlier, are subject to revision with the publication of the updated Water Resources Development Master Plan in 2008.

All basins show a decline in the Q90 flow expressed as a percentage of existing mean annual runoff, except for the Cabarita River which already has a zero Q90 value. This is expected given the estimated decline in mean annual rainfall from the climate modelling results, and the simple relationships developed between net rainfall and Q90. Nevertheless, given both the reduction from the climate models in mean annual rainfall, and also consistent results showing a decline in rainfall in the months of June-July-August, changes in low flow regimes for Jamaican rivers under climate change and increased variability are to be expected.

Table 4.18: Estimated Changes in Basin Q90 Flows, as Percentage of Existing Mean Annual Flow

Basin	1990	2015	2030	2050
I – Blue Mountain (South)	17.1%	16.8%	16.4%	15.4%
II – Kingston	12.3%	12.2%	12.0%	11.4%
III – Rio Cobre	8.0%	7.9%	7.7%	7.3%
IV – Rio Minho	14.2%	14.0%	13.7%	12.8%
V- Black River	14.2%	14.0%	13.6%	12.7%
VI – Caberita River	0.0%	0.0%	0.0%	0.0%
VII – Great River	13.9%	13.7%	13.4%	12.5%
VIII – Martha Brae River	7.2%	7.1%	6.9%	6.5%
IX – Dry Harbour Mountains	6.1%	6.0%	5.9%	5.5%
X – Blue Mountain North	13.6%	13.4%	13.1%	12.1%

Source: Water Resources Authority (WRA), 1990

Reductions in low flows in a river system, as shown in Table 4.18, indicate the placing of additional stress on the aquatic environment. For example, a reduction in Q90 flows implies shallower water depths and reduced stream flow velocities. This may reduce oxygen concentrations and raise water temperatures, resulting in stress being applied to aquatic animal species. Clearly these are preliminary observations, and further studies are required looking at the potential timing of stream flow changes (reductions) and vulnerable life stages of key aquatic species.

4.3.7 Proposed Elements of an Water Resources Adaptation Strategy for Jamaica

Although it has been possible to present more quantitative findings related to the impacts of future climate risks to the water resources sector than the agriculture sector, it is evident that much work still needs to be done to provide a sounder technical basis for the development of the required adaptation strategy projects, programmes and policies to address in a pro-active manner the issues identified here.

The imminent publication of the update to the 1990 Water Resources Development Master Plan provides a basis for this work, as will the completion of the MACC Vulnerability and Capacity Assessment project on the Vere Plains in southern Clarendon. Other ongoing projects will also provide positive contributions to this process, such as the IWCAM project implemented by NEPA and the National Forestry Plan implemented by the Forestry Department.

A number of key recommendations on the way forward to address issues of climate vulnerability and the development of adaptation projects, programmes and policy were developed as part of the V&A analysis. These recommendations were presented at a stakeholder workshop in March 2008 for review, comments, and ranking. The ranking was based on a simplified multi-criteria analysis approach that included considerations of relative cost of recommendations, effectiveness of proposed solutions, and technical/skills availability for implementing the recommendations, technology, and number of beneficiaries, political and social acceptability, environmental impact, and consistency with objectives of the National Development Plan.

Recommendations for the Water Sector

The adaptation recommendations for the water sector are presented in Table 4.19 including the rankings from the March 2008 workshop. A ranking of 1 gives the most preferred option.

Table 4.19: Climate Change Adaptation Recommendations for the Water Sector

Recommendation	Justification	Responsibility	Workshop Pooled Ranking
Formalize linkages between UWI Climate Group and stakeholders	For the results from climate modeling to be most useful for end users, it is important that the modelers understand end user needs	UWI Climate Group + stakeholders	**1**
Develop appropriate national flood risk mapping to support emergency operations and land use planning	This will result in better identification of those communities at risk from flooding and to inform land use zoning and spatial planning	WRA, Local Parishes, ODPEM, Red Cross	**2**
Increase & maintain investment in hydrological monitoring & water use with national database	This will result in improved data collection and storage on a national scale - without monitoring how do we know what is happening?	Within a regulatory body e.g. WRA, but providing access to all	**3**
Leverage and co-ordinate international funding to maximize benefits within the Water Sector	Significant investment is required in a number of areas within the sector. If multi-lateral grant-aid & bi-lateral soft loans are to be used to support this work, then the benefits accrued must be maximized, both in outputs and capacity building.	Ministries of Environment & Health, Water and Housing, Foreign Affairs and International Trade, Finance and planning.	**4**
Support & expand funding of the IWCAM programme and National Forestry Plan	One of the benefits of improved land use management practices is protection of water resources – quantities and quality	NEPA, WRA, NWC, Forestry Dept.	**5**
Develop appropriate modeling tools to assist strategic planning of water resources to supply	Linked with the above is the need to develop a consistent set of appropriate modeling approaches and tools.	Jointly across the WRA, NWC and NIC	**6**
Support & fund increased water use efficiency across all water use sectors – irrigation, domestic and industrial users	Improved water use efficiency will reduce demands on existing sources and infrastructure, reduce costs and reduce vulnerability to drought.	NWC, NIC and other water providers	**6**
Fund research into adopting water resources and water supply planning methods under climate change	There are currently no standard national approaches. With appropriate methods in place, consistent regional and national planning can take place under a changing climate	Jointly across the WRA, NWC, NIC & OUR	**8**

Recommendation	Justification	Responsibility	Workshop Pooled Ranking
Investigate shifting focus from groundwater to surface water storage for water supply.	Reduce reliance on vulnerable coastal aquifers and GW spring sources in terms of quality and quantity, with increased use of surface water reservoirs to maintain supplies.	Jointly across the WRA, NEPA, NWC, NIC and others e.g. SCoJ	**9**
Remove NWC from responsibility of Ministry of Water & Housing and place under alternative Ministerial control	Potential conflict of interest with WRA also reporting to the same Ministry. When difficult regulatory decisions are to be made, this will remove existing game-keeper / poacher perception.	GoJ ministries including Water and Housing.	**N/K**
Merge government agencies and bodies responsible for land and water protection & management into one organization under one Ministry of GoJ.	Jamaica is the land of wood and water and should be managed in that manner within a catchment / watershed framework. With divided responsibilities across GoJ Ministries, regulation, protection and adaptation can be strengthened within one Agency under one Ministry.	GoJ including Ministries of Environment & Health, Water and Housing.	**N/K**

In addition to the 11 recommendations presented at the workshop, one workshop breakout group also included the following additional options for their own consideration:

- Develop and implement a public education plan on Water Resource and Climate Change;
- Put legislative framework in place to support individual storage (cistern) systems for property developments;
- Remove political interference from science-based decision making (i.e., minimize rights to appeal decisions).

The workshop groups also made suggestions with respect to the options presented. These included the (re-)establishment of the National Climate Change Committee to provide a linking mechanism across all areas within the water sector and beyond. The need for a public education and awareness programme was also raised as being an important part of the overall adaptation response to the issues raised by the threats posed by climate change to Jamaica. The use of economic instruments (e.g., water tariffs) to modify behaviour and encourage water conservation was also proposed at the workshop. Other interesting topics were also raised related to natural dam producing processes in Jamaican rivers and their possible use as storage for local water supply, with the need to monitor the water quality of any stored waters and designing appropriate water treatment plants to ensure that a wholesome supply is provided.

The highest placed recommendation proposed formalizing linkages between the UWI Climate Group and stakeholders. This was followed by the development of flood risk mapping, and investment in hydrological monitoring. Two recommendations related to institutional (and political) reform were not assigned scores. Nonetheless, they deserve serious consideration as they seek to strengthen and co-ordinate the institutional framework for the protection of Jamaica's water sector under both existing and future climate.

4.3.8 Constraints to the Water Resources Assessment

Much of the assessment for the water sector was qualitative in nature, although some quantitative analysis was presented on the impacts from the passage of tropical storms and hurricanes. A methodology was proposed that can be refined and developed to identify WMUs and water supply zones within the WMUs that are currently vulnerable to water supply-demand deficits under average conditions, and which may become prone to deficits under future average climatic conditions. This methodology can also be developed further to investigate both potential supply and demand side measures to address deficits, which with outline engineering costs can be used to develop programmes of measures to counter the presence of these deficits.

There are also a number of other important initiatives and projects whose findings and outcomes would have greatly strengthened the analyses in the water sector. These included:

- The 2008 update to the 1990 Water Resources Development Master Plan;
- The MACC funded pilot Vulnerability and Capacity Assessment study in Southern Clarendon that brings climate change, sea level rise, water resources, and agriculture within a single project;
- The MACC funded project on the Development of a National Water Sector Adaptation Strategy to Address Climate Change in Jamaica;
- The IWCAM project focusing of watershed and land management issues.

The findings and outcomes from these activities were not available at the time of preparing the water sector analysis presented here.

4.4 Human Health

4.4.1 Main Characteristics of the Human Health Sector of Jamaica

Primary health care in Jamaica is delivered through a nested system of Type I (mainly rural) to Type V health centres, delivering progressively more comprehensive care. In 2002, there were 314 health centres in total. Type 1 centres deliver maternal and child health services and are staffed by midwives and community health aides. It is not until the level of Type 3 that a full range of preventative services is provided and a doctor is in attendance on a daily basis. Type 3 centres are located in urban areas.

The Ministry of Health operates 23 hospitals – 17 general and 6 specialists – with a capacity of just under 5,000 beds. Hospitals are also classified depending on the level of services they provide. Three Type A and four Type B hospitals are located in urban centres, with Type B hospitals serving as referrals to the 10 Type C rural hospitals. Specialist hospitals provide care for specific populations (Ward and Grant, 2005). A mix of private sector institutions and individuals also deliver a range of health care services. They provide inpatient care from seven small hospitals with 5 percent of the island's bed capacity and supply most of the pharmaceutical and diagnostic services.

Improved access to primary health care in Jamaica has resulted in an increase in life expectancy in recent years. However, some of the gains are being reversed under the impact of the HIV/AIDS epidemic, intentional, and unintentional injuries. Combined life expectancy declined from 73.3 percent in 2001 to 70.7 percent in 2004 (UNDP, 2006). The life expectancy at birth for men is 69.1 years and for women 72.5 years. The crude death rate is 6.4 percent and infant mortality 15 per 1000 live births.

Table 14.20 shows the leading causes of hospitalization and death in Jamaica in 2005.

Hospitalisation	**Deaths**
Obstetrics	Cerebrovascular diseases
Accidents and Injuries	Neoplasms
Diseases of the respiratory system	Diabetes
Diseases of the circulatory system	Diseases of the respiratory system
Diseases of the digestive system	Ischemic heart disease
Nutrition and endocrine conditions	Trauma, homicides, injuries
Diseases of the genitor-urinary system	HIV/AIDS
Neoplasms	Perinatal conditions
Infectious and parasitic diseases	Diseases of the genitourinary system
Perinatal conditions	Neuro-psychiatric diseases
Source: Ministry of Health (2005a)	

A decline in the population under the age of 15, together with increasing longevity, has resulted in a rapid demographic transition. The population over the age of 60 stood at 10 percent in Jamaica in 2001 and that over the age of 65 at 7.6 percent. The percentage of women over the age of 60 (10.1%) was slightly more than that of men (9.6%). However, while life expectancy for women is longer, health adjusted life expectancy (HALE) after the age of 60 indicates that older women spend more time in illness and with disabilities than men. Women are more likely to have vision impairments, much of which is diabetes related. While some 15.2 percent of the elderly population lives alone, men are twice as likely to live alone than women (PAHO, 2002). But as the elderly population grows, the ratio of the elderly to those who could provide care increases and this puts a burden on carers. There are vulnerable segments of the population over the age of 60 and there is a need to mainstream this segment of the population into development policies. There is a need for more information on their condition and their geographical location for they are at high risk in times of natural disasters.

At the other end of the spectrum, the population aged less than five years forms about 10 percent of the population. Table 4.6 shows the causes of death in the under-five age group in Jamaica from 2000-05 and underscores the importance of diarrhoeal diseases. Mortality in this group is 20 per 1000 live births (WHO, 2006).

Table 14.21: Causes of death in the under five age group in Jamaica (2000-05)

Disease	Percentage
Neonatal (includes diarrhoeal disease)	52
Diarrhoeal	10
HIV/AIDS	6
Pneumonia	9
Influenza	2
Others	21
Source: World Health Organization (2006)	

The burden of rotavirus gastroenteritis in Jamaica is severe. Christie *et al*. (2006) reports that the rotavirus is the major cause of diarrhoea in the age group 0 to 5. Normally outbreaks occur in the cooler months which are also drier and when water sources are compromised. In 2003, however, a large outbreak occurred in summer and affected children up to the age of eight. The outbreak was responsible for an increase in hospital admissions and deaths and was associated with flooding and faecal contamination caused by extremely heavy rains. Twenty one children died in 2003 and 24 in 2004 (Christie *et. al.*2006). The annual seasonal outbreaks continued with occasional summer peaks. For example, in 2005, the year in which torrential rain was caused by two early hurricanes – Dennis, in July, and Emily a week later – there was a summer peak in diarrhoeal diseases also. These high rainfall events have been a feature of the decade and the projection is that they are quite likely to be one of the most significant and immediate consequences of climate change in the Caribbean. Under such circumstances it is likely that the extraordinary may become the ordinary (UNDP/Harvard, 2005).

Health professionals are pinning their hopes on new rotavirus vaccines but while medical technology has a role to play, more attention is also needed for community development and the provision of safe water supplies to increase the resilience of vulnerable sections of the population. Many have questioned the effectiveness of improved environmental conditions in the control of the rotavirus since children of higher socio-economic status are also affected. There is a suggestion, however that the effect of socio-economic status is mediated by sanitary conditions (Genser *et al*., 2006). Malnutrition is also an important risk factor for diarrhoeal diseases and although national rates have declined over the past two decades (CFNI, 2003); the situation differs at the sub-national level. The risk is high in some rural areas, among the unemployed and in poor urban communities and responses must be specific to particular settings.

4.4.2 *The Institutional Arrangements for the Management of the Health Sector in Jamaica*

The adaptive capacity of a country to respond to climate change related health impacts depends to a large measure on the efficiency of the health system. Until 1997, health care in Jamaica was organized, delivered, and coordinated centrally by the Ministry of Health in Kingston. Under the National Health Services Act of 1997, the functions of the Ministry were decentralized. Delivery was assigned to four regional bodies, while policy, planning and purchasing functions were retained by the Head Office. The objective of the exercise was, in part, to make the system more sensitive and responsive to local needs. The South Eastern Region embraces Kingston, St Andrew, St. Catherine and St. Thomas and comprises 47 percent of the population. The smallest region, with 14 percent of the population, is the North Eastern, comprising the three parishes of Portland, St Mary, and St. Ann. The Western Region comprises the parishes of Hanover, Trelawny, St. James, and Westmoreland, with 17 percent of the population, while the Southern Region (St Elizabeth, Manchester, and Clarendon) accounts for 22 percent.

Decentralization of services were supposed to confer several benefits to the populations served – greater sensitivity to local preferences, reduction in inequalities, cost containment in view of sharper targeting, greater capacity to involve local community. An evaluation of the impact of decentralization in Jamaica concluded that the actual benefits were less than expected and there were minimal improvement in service delivery or in the health of the population of the districts (PAHO, 2007).

A major problem appears to be under-financing. The activities of the region are financed by a grant from the government and, until its recent removal, user fees. Despite increases in the grant, there is a resource gap. In March 2004, the debt of the Regional Health Authorities was J$3.8b (Bailey *et al,* 2007). This has affected the ability of the regions to attract trained technical personnel. In 2001, the staff vacancy rate for medical technologists was 69 percent, and the percentages for registered nurses, pharmacists and public health inspectors were 55, 51 and 29 respectively (Bailey *et al,* .2007).

Deficiencies have also been identified in the areas of training and research. The Ministry of Health has encountered problems in the diagnosis and treatment of dengue haemorrhagic fever both in the health centres and among private physicians. The problem is being addressed through staff training through the Medical Association of Jamaica as well as direct contact with private physicians (Huntley, 2008).

However, in a contentious league table which ranked the health system of 191 countries on the basis of their ability to use resources efficiently, Jamaica was given eighth place; above Japan (9th), the United Kingdom (24th) and the USA (72nd) (WHO, 2000b). The World Health Organization found that many countries performed at just 20 percent of what they could achieve while others performed at 99 percent. WHO recommended funding through prepayment schemes such as social security, taxes and insurance, rather than out of pocket. Jamaica is, therefore, making best use of limited resources but better funding will be necessary to improve the responses to impending changes.

<u>National Health Policy (2006-15) & Strategic Plan (2006-10)</u>

In the National Health Policy (2006-15) and Strategic Plan (2006-10), the Ministry of Health outlined the policy context in which priorities for health were developed (MOH, 2005). The Millennium Development Goals were taken into account, with plans to target the health of mothers and their children, infectious diseases especially HIV/AIDS and malaria, water and sanitation, as well as access to essential drugs.

The national context was also taken into consideration, i.e., the physiographic, demographic, economic, and social realities of the country. However, despite accidents and injuries being the leading causes of morbidity and mortality, and diabetes and hypertension increasing causes of concern, the outcome indicators of the plans are heavily weighted in favour of risk/lifestyle behaviours – drug use, sexual practices, road safety, and obesity.

The possible impact of climate change on health is not specifically mentioned. However, surveillance of internationally notifiable nationally monitored newly emerging and re-emerging diseases are mentioned as goals. Emerging and re-emerging diseases are considered a consequence of the ecological changes associated with climate change and the unsustainable use of resources. So there is some recognition in the Plan, though not explicit, of the likely effects of climate change.

Moreover, in response to the threat of emerging and re-emerging diseases as well as the anticipated changes in vector borne diseases, the Ministry of Health prepared a national vector control plan with the goal of re establishing a Vector Control Unit in the Ministry (Huntley, 2008). The plan makes proposals for financing in the areas of staffing, procurement of supplies, adaptation of new technologies and strategies for vector control, the strengthening of surveillance systems, and the improvement of inter-sectoral, inter-agency capacities and research.

Staff shortages are affecting the vector control programme since parishes are not adequately staffed to conduct surveillance at the levels required and with the projected increase in abundance (Huntley, 2008). There is some surveillance of high risk communities and at ports of entry, however significant percentage of the surveillance equipment was non-functional (PAHO, 2001). The virology laboratory is under-equipped. The Ministry of Health has also identified a need for operational research into the best method of control for the local population of the *Aedes aegypti* mosquito and other vectors.

Other relevant organizations

Prevention, preparedness and enhanced response to the health threats posed by climate change require inter agency and intersectoral cooperation. Already, some key agencies in Jamaica are working together on health issues, although more focused on disaster related health concerns.

The National Environment Planning Agency is an agency of the Ministry of Health and the Environment. Its mission is to promote sustainable development by ensuring protection of the environment.

The Office of Disaster Preparedness and Emergency Management has a mandate to develop and administer disaster preparedness policies and to manage all aspects of disaster mitigation. It does so by working in partnership with other agencies, an approach which allows it to influence national risk reduction (Heslop-Thomas *et a*l, 2008). In so far as climate change is concerned, sea level rise and the inundation of coastal areas, with resulting population displacement, are the Office's areas of greatest concern. Health is not seen as a part of their mandate, per se (Heslop-Thomas *et al.*, 2008).

The Meteorological Service provides warnings and advice on hazardous weather phenomena. In an interview, a representative saw their role as far as climate change was concerned in terms of conducting research on adaptation for those sectors that may be affected by the phenomenon, and communicating the information both to the stakeholders and the public (Heslop-Thomas *et al*, 2008). There was full appreciation of the health implications of climate change – those related to heat stress, respiratory diseases as well as the role of higher temperatures in the transmission of vector borne diseases.

The National Water Commission has a mandate to provide potable water and waste water services to Jamaican communities except those small rural communities that are the responsibility of the parish councils. It is also responsible for urban sewerage systems. The work of the Commission is backed up by a well-established legal framework and it has a fairly sound reputation for monitoring the quality and levels of ground water which accounts for 84 percent of available water and 92 percent of all water used in Jamaica (Karanjac, 2005). However, PAHO has raised concerns about the ratio of sampling to population served and the different standards used by different parishes (PAHO, 2004). Some problems stem from limited financial resources. Infrastructure has failed to keep pace with population growth and some pipes are more than 60 years old with issues of rust, leakage, and blockages (Neufville, 2000).

Experts say that if the entire city were connected to a working and environmentally friendly sewerage system, water sources would be protected and large amounts of water in aquifers that are polluted at present would be recovered. At the moment only 24 percent of households are connected to sewerage systems (Neufville, 2000).

The Water Resources Authority is responsible for the regulation, conservation and management of the water resources of the island, and provides technical advice to the government and its agencies. The Water Resources Development Master Plan, updated in 2008, provides a complete inventory of the water resources, including the level of availability and demand (Jamaica Observer, August 11, 2008).

The Forestry Department conserves and protects the island's forests, manages forested watersheds, protected lands and forested lands and gives advice to private land owners on the management of private forests. They also develop programmes for soil conservation. Their mandate covers a resource that is vital to the development of sustainable water supplies.

Most of these agencies already work together on sub committees of the National Disaster Committee which, under the National Disaster Action Plan, is responsible for disaster policy. A flood warning system involving the Meteorological Office, the Water Resources Authority and Office of Disaster Preparedness and Emergency Management (ODPEM) exists and this association has allowed the incorporation of flood warnings into community preparedness activities. There is an automatic (real time) warning system and community operated warning systems covering vulnerable communities. Information is relayed to ODPEM when a critical level is reached and response teams at the community level make decisions as to whether evacuation to emergency shelters is necessary.

In addition, a great deal of research has been done in the area of hazard risk assessment in Jamaica. Flood plain maps exist for river systems and multihazard assessments for the Kingston Metropolitan Area have been undertaken. These document vulnerability to seismic events, landslides, and coastal storm surges (Ahmad and McCalpin, 1999). In addition, the Caribbean Disaster Mitigation Project undertook a study to estimate storm effects in the Caribbean Basin and the storm hazard maps of Jamaica focused on key areas of vulnerability – Montego Bay, where there is intense shoreline development associated with the tourist industry; Kingston, the capital and major port; Port Esquivel, an oil terminus on a shallow bay; and Rocky Point, a railway and bauxite terminal on a shallow bay (CDMP/OAS, 2000).

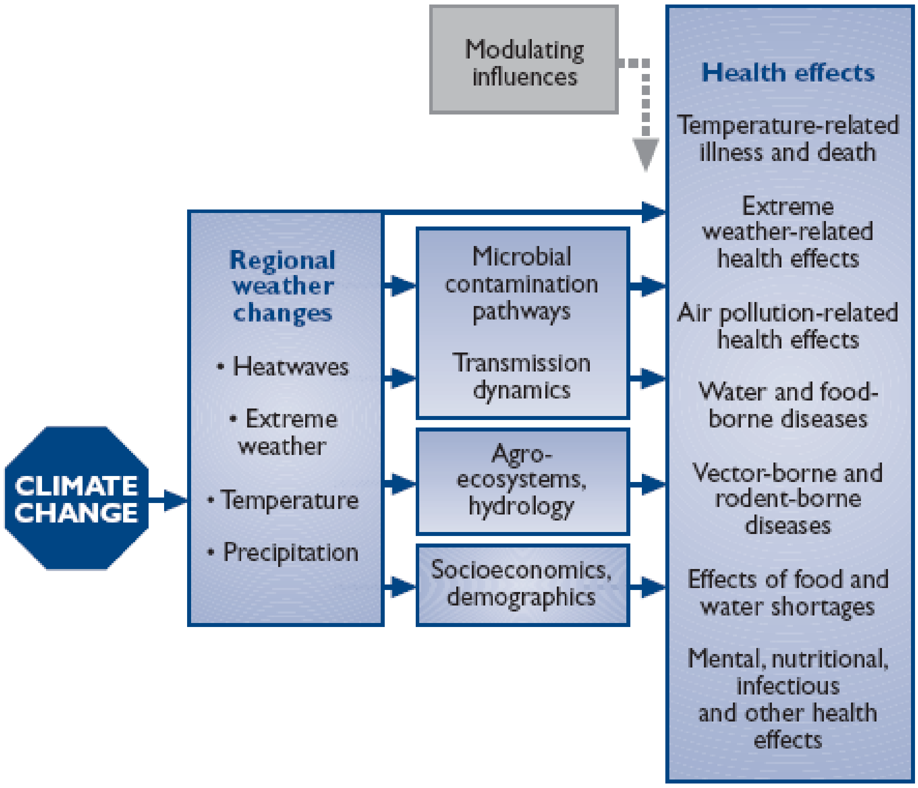
There are also international organizations involved in emergency preparedness and response. UNICEF, for example, in response to its mandate to protect disadvantaged children supports the activities of ODPEM in the wake of disasters, supplying food, shelter and emergency kits. As a result, there is a relatively high level of preparedness for disasters. IADB/ECLAC (2007) has pointed to several areas where improvements are necessary – community preparedness, increase in emergency stocks, emergency water supplies, and improvement in community shelters. But as important as these initiatives may be, they cover just one aspect of the preparedness and they are not sufficiently focused on people and the health impacts of the hazard. A similar structure but one that is more inclusive, that is capable of providing a response to the broader health implications of climate change is necessary.

4.4.3 Vulnerability of the Health Sector in Jamaica to Climate Change

General overview of the impacts of climate change on health

A comprehensive review of the issues related to climate change impacts on health has been produced in a book called *Climate Change and Health: Risks and Response* by Mc Michael et al. (2003). The various pathways by which climate change can impact on human health are complex, as shown in Figure 4.15.

Figure 4.15: Pathways by Which Climate Change Affects Human Health, including Local Modulating Influences and the Feedback Influence of Adaptation Measures



Source: McMichael et al. 2003, adapted from. Patz et al, 2000

The direct impacts on health are mainly those due to changes in exposure to weather extremes. These include extremes in temperature (heat waves and winter cold in temperate regions), extremes in precipitation (floods and droughts), and extremes in wind (cyclones and storm surges). Increased production of certain air pollutants and aeroallergens (spores and moulds) may also be directly linked to the weather. The impacts of climate change will depend on the extent of change in the frequency, intensity and location of extreme weather events due to climate change, which remains uncertain.

Climate change, acting via less direct mechanisms, could also affect the transmission of many infectious diseases (especially water, food, vector-borne, and rodent-borne diseases) and regional food productivity (especially cereal grains). In the longer term, these indirect impacts are likely to have greater magnitude than the more direct (McMichael et al., 2001, and Epstein, 1999). Other illnesses, such as mental stress, could also be indirectly be impacted by climate change.

Climate change is only one of several important factors influencing the incidence of infectious diseases. Other important considerations include human migration and transportation; drug resistance and nutrition; environmental influences such as deforestation; agricultural development; water projects; and urbanization. In this era of global development and land-use change, it is highly unlikely that climatic changes exert an isolated effect on disease. Rather, the effect is likely dependent on the extent to which humans cope with or counter the trends of other disease modifying influences. While recognizing the important independent role of these non-climatic factors, the focus of this section is to examine the extent to which they may compound the effects of climatic conditions on disease outcomes.

<u>Vulnerability of the Health Sector in Jamaica and the Caribbean to Climate Change</u>

Jamaica is at the point in the epidemiological transition in which, while non-communicable diseases are the leading causes of death, the health system must still cope with infectious and parasitic diseases as well as rising levels of HIV/AIDS and intentional and unintentional injuries. Table 4.22 shows the varying sensitivity to climate changes to the communicable diseases that can affect the Jamaican population.

Table 4.22: Sensitivity of Communicable Diseases to Climate Change in Jamaica

Very weak	Some sensitivity	Moderate	Strong	Very strong
Intestinal nematodes	Influenza Diarrhoeal diseases	Meningococcal meningitis	Dengue	Malaria
Source: World Health Organization (2000a)				

With respect to the leading causes of death in Jamaica (Table 4.20), heat stress increases susceptible to a high incidence of cerebrovascular diseases, but this is considered to be of greater importance in cold than in hot countries. This problem, however, could be exacerbated by the construction material used and the design of housing. Buildings need to be designed to reduce heat stress and vector-borne diseases.

Of the respiratory conditions prevalent in Jamaica, asthma is a cause for concern with respect to climate change. Rising carbon dioxide levels could increase allergenic plant pollens. Increasing quantities of dust clouds containing minute particles and microbes are blown into the Caribbean from the Sahel region of Africa. The African/American atmospheric system is a long standing phenomenon. However, human activity in the expanding desert region of Africa has intensified the problem and dust concentrations in the Caribbean are correlated with rainfall deficits in the Sahel. Climate change and increasing drought could therefore have a significant effect on the concentration of dust. Researchers in Trinidad and Tobago report a correlation between paediatric admissions for asthma and increasing Saharan dust cover (Gyan, et al., 2005. See also McCarthy, 2001). Asthma-related visits to health care institutions in Jamaica comprised 6.3 percent of all visits and a prevalence study is being conducted to provide crucial data on its prevalence (*Jamaica Observer*, December 1, 2006).

Various aspects of community health are also vulnerable to climate change impacts, including sanitation, water supplies, and disaster responses.

The National Water Commission estimates that about 75 percent Jamaican households have access to piped water in their homes and 11 percent obtain water by other means, including standpipes. In other words, about 85 percent of the population has access to a piped supply. Roughly 20,000 households have no excreta disposal facilities (PAHO, 2007). Many of these households are in informal settlements. This has implications for the spread of infectious and water-borne diseases (where water supplies are contaminated).

As in other islands in the Caribbean covered by limestone formations, the ground water is very vulnerable to contamination. Karanjac (2005) has listed several threats, some of which will be intensified with climate change and have potential effects. Sea level intrusions are already affecting the aquifers along the south coast of Jamaica and some wells have had to be abandoned. The thin layers of soil overlying the white limestone formations allow contamination by industrial and agricultural processes, as well as by septic tanks and soak away sewage disposal systems. The karstified nature of the rocks allows contaminants to move long distances from the point of origin. Alluvial aquifers are also contaminated. This has implications for the spread of water borne diseases.

Added to considerations of water safety are those relating to sufficiency under climate change? The projections indicate increased frequency of droughts. The problems experienced by communities that lack surface water storage and are dependent on springs and rivers such as St. Mary and Clarendon, for example, could become increasingly vulnerable to diseases caused by reduced effluent dilution and increased pathogen loading. Despite inter catchment transfers, the large urban population in the Kingston Metropolitan Area (KMA), already subject to periodic rationing, is also likely to experience shortage in the supply.

Moreover, ensuring the safety of water and sanitation systems and water sufficiency does not guarantee protection against natural disasters. The damage to established infrastructure in hurricanes or floods can have adverse health consequences. Water supplies are interrupted and communities may resort to unsafe supplies. Treatment plants may suffer damage or may be put out of operation because of the interruption of electricity.

Outbreaks of typhoid in 1989 and 1990 were associated with the destruction of pit latrines following Hurricane Gilbert in endemic pockets in the west of the island, as well as problems of access to clean water and waste disposal facilities in the hurricane shelters provided for the poor. Conditions in the shelters give cause for grave concern. Shelter managers must cope with outbreaks of diarrhoeal diseases, the injuries and lacerations resulting from flying and broken objects, pre-existing conditions such as the foot ulcers of diabetic patients under very unhygienic conditions. No special provisions are made for the large number of children in shelters, who are exposed not only to diseases but to the dangers of a poorly supervised environment. Many of the buildings used are not intended for this purpose and attention must be paid to identifying shelters, upgrading facilities to meet the demands and ensuring adequate supervision in times of disasters.

There are implications also for food supplies. By UN criteria, Jamaica with 1,500m^3/yr of water for each inhabitant, is water stressed. Agriculture is a prime user of the resource and saline intrusion has caused the loss of agricultural land along the south coast. Although the reduction in abstraction is pushing back the saline front (Karanjak, 2005), rising sea levels could reverse these gains.

Vulnerability is also affected by surveillance programmes and efforts at vector control. Disease surveillance in Jamaica has active and passive forms. Under the passive system, reports are received from a number of public and private primary care facilities as well as hospitals, laboratories and selected hotels. This provides critical information necessary for the monitoring of community health but there are obvious draw backs to this type of dependence. Epidemiological surveillance including entomological surveillance and the monitoring of the types of behaviours that promote the proliferation of larval habitats are considered priorities by the WHO. For example, in Jamaica, the major breeding ground for mosquitoes has been found to be the 40-gallon drums that are used to store water (Chadee et al, 2008). The promotion of behavioural change through the development of guidelines for sustainable prevention and control of vectors are also WHO priorities (Heslop-Thomas, *et al*., 2008).

Jamaica's proximity to countries where malaria is endemic – Haiti, Guyana, and Suriname – geographically, but also economically, and with the legal and illegal movement of people among these countries heightens the risk of reintroduction of the disease. After a 40-year absence, an outbreak of malaria occurred in December 2006 and affected an estimated 400 persons, mainly in depressed areas of the Kingston Metropolitan Area.

Some of the geographic factors affecting vulnerability have been referred to – the island's location in the path of Atlantic hurricanes and susceptibility to high rainfall events, storms and hurricanes. These events have underscored the vulnerability of those living in environmentally sensitive areas as they cause death and the dislocation of people and economic activity. Coastal communities are not the only areas that are susceptible to these events. A combination of high precipitation, a small catchment, geology, and human influence combine to make many slopes in the east of Jamaica unstable, creating landslides. Coastal areas, unstable slopes, river courses, especially those supporting poor communities, have been shown to be extremely vulnerable to landslides and the ravages of flood waters

4.4.4 Analysis Of Future Climate Risks For Human Health in Jamaica

In addition to a literature review of the more general impacts on climate change on health worldwide (McMichael et al, 2003), a review was conducted of research being done in English-speaking Caribbean countries. It is acknowledged that useful work has been done in Cuba, especially in the area of mathematical modelling, however as yet these models have not been applied to the rest of the Caribbean. Two projects based in Jamaica that focus on dengue fever and leptospirosis are described here in some detail, followed by a brief summary of other climate change threats to human health in Jamaica, including other relevant research on diseases and climate variability.

<u>Dengue Fever</u>

Since a 2-3ºC rise in temperature can lead to a three-fold increase in dengue transmission, dengue epidemics will be a definite climatic health threat for Jamaica. It can be seen from Table 4.23 that based on a simple proportion; an estimated figure of approximately 600[31] Disability Adjusted Life Years (DALYs) would be lost in Jamaica with a population of approximately 3 million. Since all four sero-types are present in the country, the chances of dengue-hemorrhagic fever (DHF) will be increased. Serious outbreaks of dengue epidemics in Jamaica would also harm the tourist industry and this could have an

[31] This value is very uncertain since the figures in Table 4.23 are rounded to the nearest 100,000. It should also be noted that the DALYs given in Table 4.23 are conservative and other analyses give three times the values listed.

indirect impact on health because tourism is important contribution to the economy and helps to pay or health services. This threat may not be diminished by less rainfall since water is stored, especially in 40 gallon drums, during times of water shortage, and these containers are the major habitats for mosquito pupae, as noted above (Chadee et al., 2008).

Table 4.23: Main Vector-Borne Diseases, Populations at Risk and Burden of Diseases

Disease	Vector	Population at risk	Number currently infected or new cases per year	Disability adjusted life years lost[a]	Present distribution
Malaria	Mosquito	2400 million (40% world population)	272 925 000	42 280 000	Tropics/subtropics
Schistosomiasis	Water snail	500–600 million	120 million	1 760 000	Tropics/subtropics
Lymphatic filariasis	Mosquito	1000 million	120 million	5 644 000	Tropics/subtropics
African trypanosomiasis (Sleeping sickness)	Tsetse fly	55 million	300 000–500 000	1 598 000	Tropical Africa
Leishmaniasis	Sand Fly	350 million	1.5–2 million	2 357 000	Asia, Africa, Southern Europe, Americas
Onchocerciasis River blindness	Black fly	120 million	18 million	987 000	Africa, Latin America, Yemen
American trypanosomiasis (Chagas' disease)	Triatomine bug	100 million	16–18 million	649 000	Central and South America
Dengue	Mosquito	3000 million	Tens of millions	653 000[b]	All tropical countries
Yellow fever	Mosquito	468 million in Africa	200 000	Not available	Tropical South America and Africa
Japanese encephalitis	Mosquito	300 million	50 000	767 000	Asia

[a] The Disability-Adjusted Life Year (DALY) is a measure of population health deficit that combines chronic illness or disability and premature death (17). Numbers are rounded up to nearest 100 000.
[b] Other analyses suggest this value could be as high as 1 800 000 (18).

Source: McMichael et al., 2003

Research done elsewhere (Hales et al., 1996 and Poveda et al., 2000) revealed that dengue epidemics are associated with the warm episodes of El Niño Southern Oscillation (ENSO) events. Initial investigations showed that peaks in reported cases of dengue in the Caribbean occurred in El Niño years and in years immediately following an El Niño (El Niño + 1 years) , when temperatures in the Caribbean are warmer than normal. The link appears to be the adaptation of the dengue virus to temperature changes. The extrinsic incubation period (i.e., period of incubation of parasite inside the vector, or EIP) shortens and transmission increases (Focks et al., 1995 and Koopman, et al., 1991). Higher temperatures also increase the amount of feeding and so increase the probability of dengue transmission to new hosts. Moderately high temperatures hasten the larval stage, leading to smaller mosquitoes, which then require more frequent blood meal, while increased temperature also enhance metabolism.

From 2002 to 2006 Jamaica participated in the project, *The Threat of Dengue Fever - Assessment of Impacts and Adaptation to Climate Change in Human Health in the Caribbean* funded by the Assessments of Impacts and Adaptations to Climate Change (AIACC) project and executed jointly by The University of the West Indies (UWI) Mona and the Caribbean Epidemiology Centre (Chen et al., 2006a). The aims of the project were:

i) to determine the extent of the association between climate and the incidence of dengue across the Caribbean region;
ii) to identify and evaluate adaptive options to ameliorate the impact of climate on this disease;
iii) to propose adaptation strategies based on climate change scenarios;
iv) to make the knowledge gained accessible and useful to decision makers.

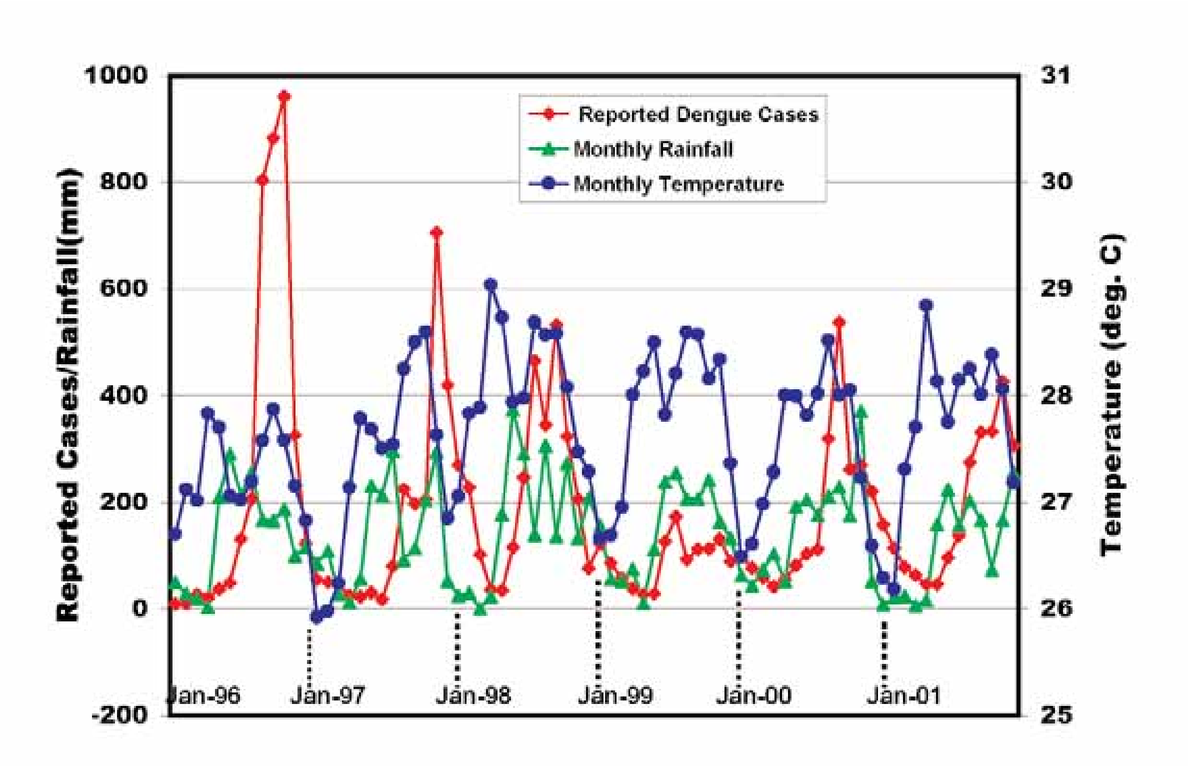
Key components of this project included retrospective and prospective studies, a Knowledge, Attitude, and Practices (KAP) survey, and identification of adaptation options such as an early warning system and response framework for dengue fever.

A. Retrospective Study (Amarakoon et al., 2006)

The purpose of this study was to investigate the nature and extent of the association between climate and the incidence of dengue across the Caribbean, and to examine temperature indices that may prove useful in gauging the potential for the onset of dengue. Data for temperature and precipitation were available from meteorological offices across the Caribbean, and data on dengue were obtained from the Caribbean Epidemiology Centre. Temperature indices to evaluate the onset of dengue were seen to be of immense value in planning preventative and adaptation strategies

The study showed that in the Caribbean, the epidemics (outbreaks) of dengue have a well defined seasonality, occurring in the latter half of the year during which the Caribbean countries are warm and wet. The seasonality was clearly present in the patterns of the disease for the individual countries. Examples are in Figure 4.16 which shows the monthly variability of reported cases, temperature and rainfall during 1996-01 in Trinidad and Tobago and illustrates the seasonality of dengue and the relationship of epidemics to temperature and rainfall. With respect to the relation between epidemics and temperature and rainfall, it is evident from Figure 4.16 that the warming occurs first, then rainfall, and then the dengue epidemic. Thus we see a simple pattern between onset of the epidemic, warming, and precipitation. Similar results were obtained in the studies from other countries.

Figure 4.16: Time Series of Monthly Reported Dengue Cases, Rainfall and Temperature in Trinidad and Tobago (1996-01)



It was also evident that the probability of an epidemic during an El Niño period (El Niño and El Niño+1 year) is higher. The results given in Table 4.24 further support this inference. Thus, it appears that dengue outbreaks have a strong association with El Niño events, probably because the latter part of the El Niño year is warmer and the early part of the El Niño+1 year is wetter and warmer. These climatic conditions are more favourable for sustaining the epidemics through increases in mosquito habitats, shortening EIP, and increasing disease transmission rates. Also, it was evident that the epidemics have a periodicity that approximately agrees with the periodicity of El Niño events. This type of periodicity has been analyzed and reported for dengue in Thailand by Cazelles *et al.* (2005).

Table 4.24: Distribution of Dengue Peaks among ENSO Phases (Source Caribbean Epidemiology Centre, 1980-2001)

Region	Total	El Niño + 1	La Niña	Neutral
Caribbean	8[a]	7	–	1
Trinidad & Tobago	8	6	–	2
Barbados	6	5	–	1
Jamaica	5	4	–	1
Belize	4	3	1	–

a Number includes year 1992, which is on the rising side of the peak in 1993.

Detailed analysis of the annual reported cases and climate parameters (temperature and rainfall), yearly patterns of disease and climate parameters, including lagged cross- correlation studies revealed the following results:

i. Correlation of annual reported cases with temperature and rainfall indicated that the association with temperature is much stronger than that with rainfall;
ii. During years in which warming or rising temperatures occurred earlier, the onset (initial appearance of the clinical cases) of the disease and the transformation to an epidemic appeared to occur earlier than usual and the onset together with the transformation closely followed the epidemic of the previous year. This feature was more pronounced if the previous year was a warmer one;
iii. In many years, start or onset of the disease generally appeared to occur during the summer period, following the early temperature peak by a few weeks;
iv. The moisture availability was observed to be necessary for the onset of dengue, but the amount of moisture did not appear to be critical for the onset.

A temperature index, MAT

A temperature index was developed to gauge the potential for the onset of dengue. The best index was a moving average of monthly temperature, which was given the name Moving Average Temperature (MAT). The average value of MAT (AMAT) over a number of years was also calculated. Figure 4.17 shows a combined graph of MAT, the corresponding number of reported cases for Trinidad and Tobago for the years 1992, 1994, 1999, and 2001 and the value of AMAT for 1979-01 (27.2º C). Note the onset of the epidemic four to six weeks after the MAT crosses AMAT in 1999 and 2001 and eight weeks afterwards in 1994. Note also the slow approach to AMAT in 1992 associated with late start of onset of dengue fever.

Figure 4.17: Reported Dengue Cases, Moving Average Temperature (MAT), and Average MAT in Trinidad and Tobago (1992, 1994, 1999 and 2001)

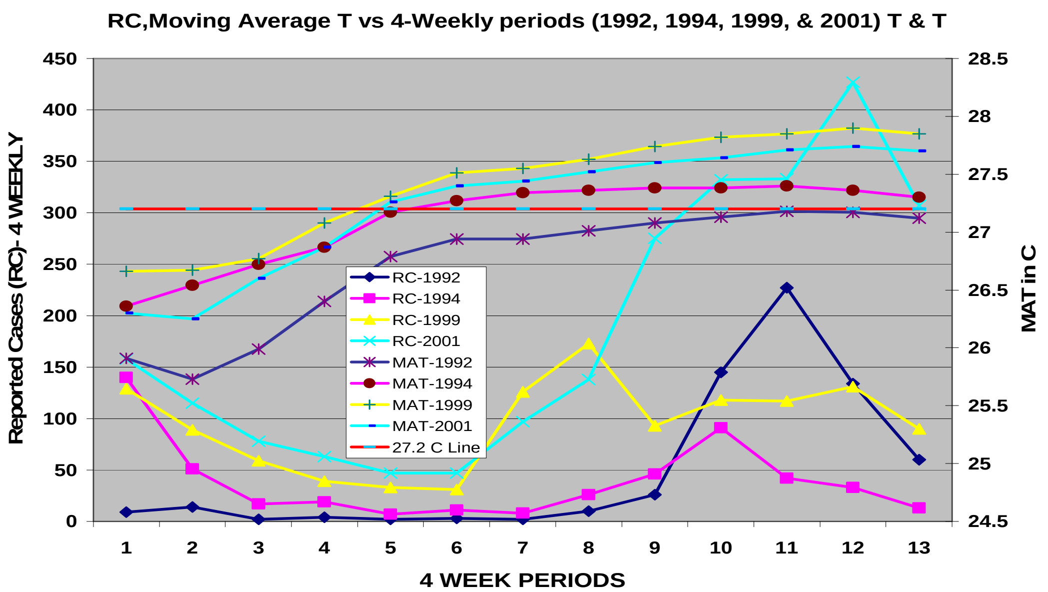
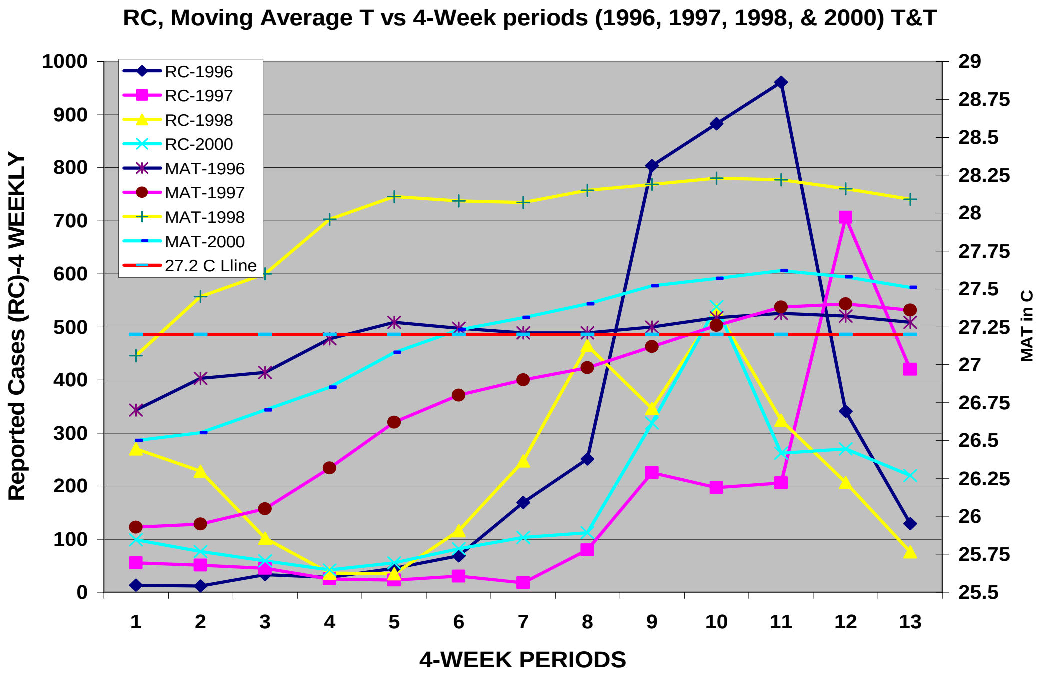


Figure 4.18 shows a similar graph for 1996, 1997, 1998, and 2000. In this graph, the early crossing of AMAT in 1998 is associated with the early onset of the epidemic and the slow approach in 1997 is associated with late onset. The crossings in 1996 and 2000 coincide with onset. It does appear that the time at which the AMAT is approached or reached can be used to gauge the potential for the onset of an epidemic; it appears to be the forbearer of the disease.

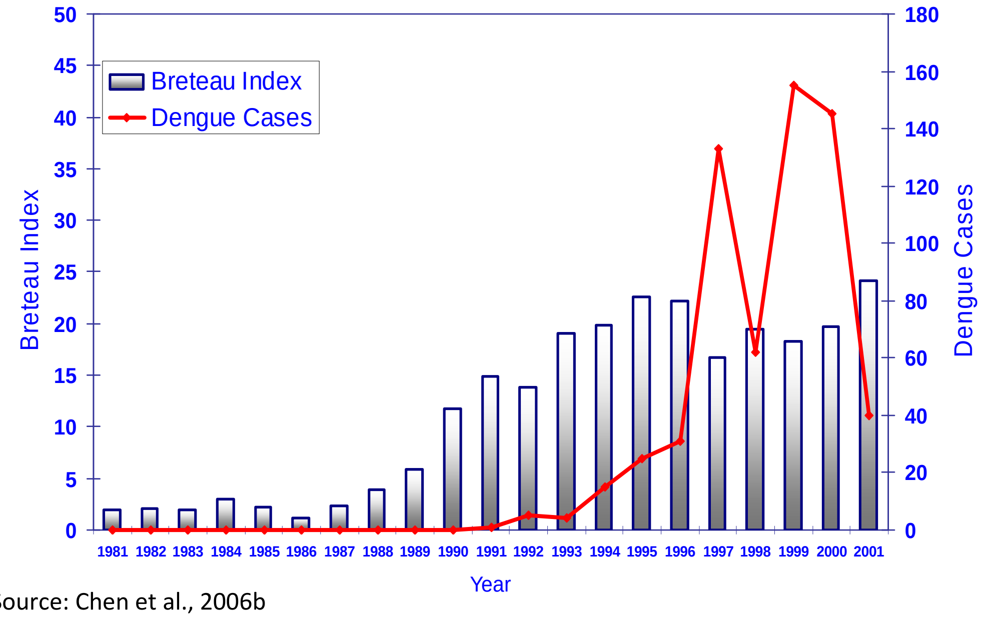
Figure 4.18: Reported Dengue Cases (RC), Moving Average Temperature (MAT) and Average MAT in Trinidad and Tobago (1996-98 and 2000)



B. Prospective Study

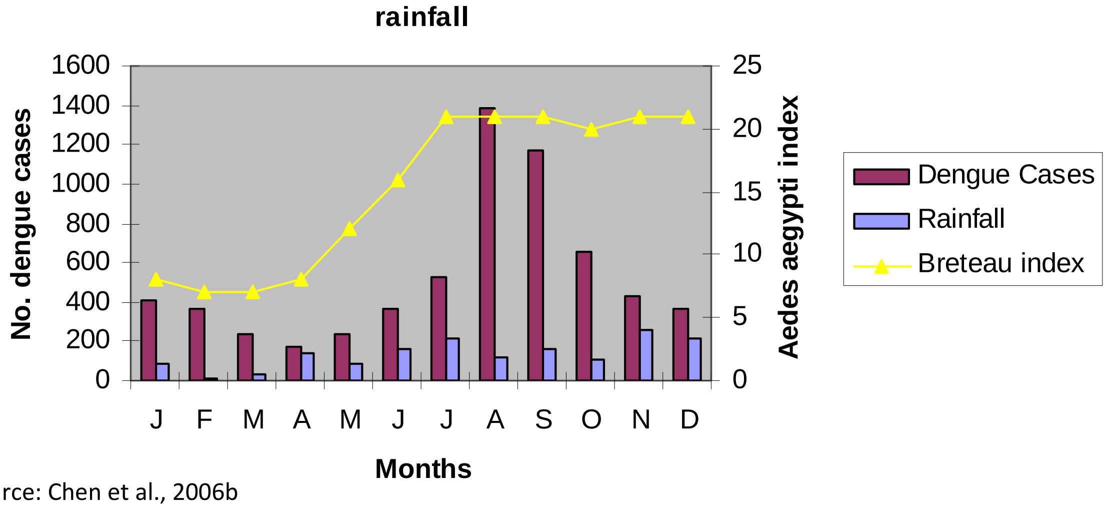
An index for measuring the prevalence of mosquitoes is the Breteau Index, which is the number of containers positive for larvae or pupae of the *Aedes aegypti* mosquito (dengue vector) per 100 premises. Figure 4.19 shows the Breteau Index measured in Trinidad and Tobago from 1981-01 and the corresponding number of reported dengue cases. The Breteau Index starts to increase before the number of reported cases and shows potential as a predictor of dengue. Figure 4.20 shows the monthly distribution of the Breteau Index, reported dengue cases and rainfall during 2002, when the prospective study was done. It clearly shows that the Breteau Index starts to increase about a month before an increase in dengue cases is reported.

Figure 4.19: Time series of Breteau Index and Reported Dengue Cases in Trinidad & Tobago (1981-01)



Source: Chen et al., 2006b

Figure 4.20: Breteau Index, Dengue Cases and Rainfall in Trinidad & Tobago (2002)



Source: Chen et al., 2006b

C. Knowledge, Attitude and Practices (KAP) Survey

In determining vulnerability and adaptation, it is good to know a population's knowledge, attitudes and practices (KAP) with respect to the environment and climate change. Such information can guide recommendations for adaptation to climate change by pointing to models of intervention (e.g., educational or environmental?), mobilization (e.g., community and/or national level participation?) and adaptation (e.g., early warning systems).

KAP surveys were carried out in Trinidad and Tobago, St. Kitts-Nevis and Jamaica as part of the AIACC project. Although the diseases concerned in the survey were dengue fever and dengue haemorrhagic fever, the results and conclusions would be applicable to all vector-borne and environmental related diseases. The knowledge gained form this study is therefore timely. A description of the results of the KAP survey follows (Rawlins and Bailey et al., 2006).

Study design: A questionnaire was used to solicit information from various communities in Trinidad and Tobago, St. Kitts-Nevis, and Jamaica on their knowledge, attitudes and practices relating to dengue fever. There were questions relating to the demographics of respondents; their understanding of the concepts of climate change and climate variability; knowledge of dengue fever and its transmission; attitudes towards disease prevention; and actual disease prevention strategies used by the communities. A randomly stratified sampling method was adopted for all three countries.

A representative sample of 300 respondents was selected from communities in urban and rural Jamaica. An attempt was made to select communities that were broadly representative of the Jamaican population. Clusters were selected from inner city and suburban middle/high income areas in the Kingston Metropolitan Area and a community in rural St. Andrew, as well as an urban and rural community in the parish of St. James. It was known from the fragmentary data on the occurrence of dengue fever in 1998 that some members of the rural community in St. James were infected with dengue fever during that outbreak. Two hundred and forty-two heads of households, or just over 80 percent of the selected sample, agreed to take part in the survey.

Results: Of the 242 respondents, 61 percent were female and 39 percent male. Sixty percent lived in urban areas and the rest in rural. Since 53 percent of the population of Jamaica has been classified as urban, this segment of the population was slightly over-represented in the sample. The largest single age cohort represented was the 24-34 age category, which formed 30 percent of the sample. This was followed by the 35- 44 age group. Over 91 percent of respondents were below age 65. The largest band for educational attainment was secondary education, accounting for 49 percent of respondents. Those with a tertiary education comprised only 8 percent of the sample. Insofar as educational attainment was concerned, the Jamaican sample was similar to that of Trinidad and Tobago, but below the level reached in St. Kitts-Nevis. Most respondents were employed and those who lived on their own were mainly renting. Forty-eight respondents said that they had had dengue fever in the past and, of these, 69 percent had contracted the illness on one occasion and 20 percent on two or more occasions. Males were more likely than females to have the dengue fever diagnosed by a medical practitioner.

- *Understanding the concept of climate change:* Most respondents did not have a clear understanding of the term "climate change". The largest single group (31%) felt that the term referred to short-term fluctuations in the earth's climate. Less than 24 percent regarded it as an increase in the earth's temperature, and almost as many saw it as involving both temperature and rainfall increases. The number giving the correct response (of long term fluctuations in the earth's climate) was 22 percent.

- *Causes of climate change:* An equal number believed that climate change was the result of the pollution of air, water, and land resulting from man's activities (34%) as those who thought it the work of God (34%). A further 30 percent of respondents felt that the process was the result of supernatural phenomena. The supernatural element assumed greater importance in Jamaica than in the other islands. Only three persons claimed that they did not know the cause of climate change, compared with more than 30 in Trinidad and Tobago and St. Kitts-Nevis.

- *Sources of information on climate change:* Respondents received climate change information from various sources, including their peers, family members, neighbours, and electronic and print media. The dominant source of information was the electronic media, mentioned by 23 percent of the respondents. This was followed by peers (18%) and the newspaper (percent not available). As in the other countries, family and neighbours were the least important as sources of information on climate change.

Responding to a question as to which areas of their lives were likely to be affected by climate change, respondents gave a variety of responses. However, health was the most frequent response (29%), closely followed by agriculture (28%), water (27%), and biodiversity and coastal degradation (11%). Others mentioned the possibility of natural disasters and soil erosion. In all countries surveyed, health emerged as the area of greatest concern. Those who expressed concerns about health effects felt that climate change would result in an increase in the occurrence of diseases (89%), facilitate a more rapid spread (3%), and increase mortality (3%).

Only 4 percent of the respondents in Jamaica claimed that they did not know the mechanism through which climate change would exert its effects on health. In Trinidad and Tobago and St. Kitts-Nevis, the number not responding to this question was 54.3% and 56.6% respectively. In addition, respondents felt that climate change would exert an effect on water bodies, primarily through pollution (57%) and drought (17%). It was also assumed that there would be a loss of crops and livestock, thereby creating food shortages, extinction of species and the destruction of the corals off the coast of the island. Over a quarter of the respondents were unable to specify the mechanisms causing loss of biodiversity (28%) and coastal degradation (24%).

- *Potential link between climate change, climate variability and dengue fever:* A significant number of respondents perceived an increase in the incidence of dengue fever in the wet season (73%); only 1 percent cited a link with the dry season. A substantial minority (25%) could not make any association. Those associating dengue fever incidence with the wet season argued that an increase in rainfall increased the number of breeding sites of the mosquito (62%) and also affected virus replication (17%) and life cycle (15%) of the vector. High temperatures were also believed to affect the development and life cycle of the mosquito. One of those who associated an increase in transmission with the dry season felt that was caused by an increase in water storage. More than half the respondents (57%) suggested the possibility of an increase in dengue fever transmission resulting from climate change given an expected increase in temperature and rainfall. However, 31 percent of the respondents could see no relationship between climate change and the occurrence of dengue fever.

- *Knowledge of dengue transmission and disease symptoms:* Eighty per cent of respondents knew that dengue fever was transmitted by a mosquito, however only 29 percent knew the name of the mosquito (*Ae aegypti*) responsible for dengue fever transmission in the Caribbean. Respondents in urban areas were more likely than those in the rural areas to know that mosquitoes were vectors, although the difference was not statistically significant. The percentage claiming that they did not know was almost twice as large in rural as in urban areas. However, of those who knew that mosquitoes were vectors, significantly more rural respondents were able to name the mosquito and this was influenced by the high level of knowledge gained from prior exposure to dengue fever outbreaks in rural St. James (66%). With respect to the respondent's knowledge of the symptoms of dengue fever, it was not surprising that most respondents (77%) named fever, followed by pain (57%) and rash (30%).

Respondents in the upper income area in the Kingston Metropolitan Area limited their responses to these three classical symptoms of the disease. In rural St. James especially, conditions such as dizziness, weakness, upset stomach, vomiting and loss of appetite were listed. Relatively few (27%) were able to distinguish between the symptoms of dengue fever and dengue haemorrhagic fever. In fact, very little was known about the latter.

- *Attitudes to the disease:* Almost 91 percent of the Jamaican respondents considered dengue fever as a serious disease, with only 7 percent not considering it to be serious or very serious. In view of the seriousness of the disease, medical intervention was thought to be necessary (94%). Respondents felt that such intervention was more likely to relieve the symptoms (92%) than cure the disease. A significantly higher number (59%) considered dengue haemorrhagic fever a serious or very serious disease. Thirty-nine percent claimed they did not know the answer to this question.

- *Dengue prevention:* Respondents gave a number of responses as to their views on the best methods of preventing the breeding of mosquitoes. The employment of pesticides – oils, sprays – was the most popular choice (44%). Others felt that environmental sanitation (29%) and public education (27%) were most likely to yield results. Spraying was also seen as the best method of controlling the adult mosquito (62%) since it was effective in killing them (60%) and it was efficient in that it covered a wide area rapidly. But those who objected to spraying were concerned about its health effects and about the mosquitoes developing a tolerance to sprays. Those who harboured anxiety about the health effects of the use of pesticides had more confidence in public education and environmental sanitation than in the use of pesticides.

Responsibility for dengue control was seen primarily as that of the Ministry of Health (30%), followed by the individual, the community, and the family. Eighty-one per cent felt that enough was not being done by the Ministry of Health to control vectors – there was no public education (65%) campaign (almost 90 percent of those interviewed felt that there was an urgent need for this), no organized community clean-up exercises (66 %) and no regular spraying. Almost 44 percent could not recall the last time that their community had been sprayed. The majority expressed a willingness to be involved in public education campaigns centred on dengue fever.

- *Practices:* In all, 79% of the respondents said that they made an effort to control the breeding of mosquitoes around their homes through various forms of environmental sanitation methods. Although those who believed that the individual had a responsibility to control the vector were more likely to give a positive response, the difference was not statistically significant. About 59 percent made an effort to protect themselves from being bitten by mosquitoes while indoors, which is where they felt they were more likely to be bitten. Repellents were the most popular choice overall. Fewer (25%) protected themselves when outdoors and while repellents were also favoured for outdoor protection by urban respondents, rural respondents mentioned smoke and the use of clothing.

Respondents were asked what preparations they made when they were warned that their community was to be sprayed. Forty-one per cent said that they closed all windows and doors (which defeat the purpose, since the *Ae aegypti* mosquito is domiciliated). Thirty four per cent opened doors and windows, and the rest made no preparations. There was a significant difference in the practice of those who had objections to the use of spraying and expressed a preference for public education as a form of control, and those who believed in the use of pesticides. The former was more likely to close doors and windows than the latter.

The survey revealed that there is a deficit in knowledge of climate change at the community level. More than 50 percent of the sample could not define the term or state the cause of climate change. A large sector of the population ascribed the phenomenon solely to supernatural causes and the implication of this was that they did not have an understanding of their role in contributing to and mitigating the effects of change. There was also a paucity of knowledge of dengue fever and many respondents had extreme difficulty in establishing a link between climate change and the transmission of the disease. It is quite possible that if more information on climate change within the Caribbean and its link with outbreaks of dengue fever were made available to the public, it might stimulate more interest and the concept may be less of an abstraction than it appears to be at present. To this end, the electronic media that seems to be an important source of information could be mobilized.

There is also need for more public education on the transmission of dengue fever and especially of dengue haemorrhagic fever. The symptoms of dengue fever appeared to be well known but there has been little experience of dengue haemorrhagic fever in Jamaica, hence knowledge is correspondingly low. However one of the effects of the circulation of several serotypes and the possibility of increased transmission consequent on climate change is an increase in the incidence of dengue haemorrhagic fever. At the moment, it appears that there is no appreciation of the seriousness of the disease. As far as public health adaptive strategies are concerned, the WHO has emphasized the benefits of public education programmes and the need for the population to be informed about the possible consequences of sequential infection and the nature of the threat posed by dengue haemorrhagic fever (PAHO, 1994). This level of awareness can only come about through a public education programme. Research has shown, however, that because of resource constraints, very little attention is being given to public education campaigns. Respondents in the study have shown that they recognize the benefits of a public awareness campaign, as well as the neglect.

It is widely believed that the primary responsibility for vector control is the governments (PAHO, 1994). However, communities have an important role to play and the two must work in concert. The survey has shown that most respondents viewed vector control as a government responsibility. However, what was significant was that those who saw that the individual had a role to play also tended to play an active part in vector control. This underscores the need for public education as a tool to empower communities to play an active part in vector control. One very positive aspect of the survey was the high level of willingness displayed by communities to work alongside the government in eliminating mosquito breeding habitats through community clean-up exercises; 79 percent indicated that they would support such a venture. There were many who were not convinced of the efficacy or advisability of spraying as a means of vector control. These were the respondents who placed the emphasis on environmental sanitation. Spraying is sometimes used, often in response to community complaints of high levels of infestation. However such exercises become more of a waste of resources if houses are closed to exclude the pesticide. It is possible that such actions may be taken in ignorance of the habits of vectors. The need for public education and cooperation between communities and public health authorities to devise the best strategies for vector control and the reduction of transmission cannot be overstated.

The KAP study showed that in St. Kitts-Nevis and Trinidad and Tobago, respondents demonstrated good knowledge about climate change, attitudes to climate change/climate variability and the use of this information for adaptation for dengue fever prevention. However, the knowledge and attitudes of the

Jamaican respondents were less than that those observed in Trinidad and Tobago. The major issue highlighted was the use of such knowledge (knowledge into action). At the time of the survey, no effort had been made in Jamaica to highlight climate change/climate variability as an important risk factor for enhanced dengue fever transmission, thereby developing adaptation during periods of predicted high risk which could be a valuable additional tool to prevent disease transmission.

The burden falls on the scientific community to:

- Demonstrate clearly to the public, the links between climate change and dengue fever. It is possible to make a case for risk predictability and apply this for vector and disease mitigation;
- Promote climate change information, using alliances of health education for best community involvement and possible positive responses;
- Stimulate research on climate change and other public health issues; and
- Promote cross-disciplinary initiatives and studies on climate change and the environment.

D. Early Warning System & Response Framework (Chen et al., 2006b)

A final aspect of the AIACC project was to identify potential adaptation options. Using the MAT and Breteau Indices described earlier, a simple early warning system for dengue can be devised. The two indices in themselves will indicate only the presence of conditions necessary for a disease epidemic. For the disease to spread, the following factors must be present:

1. presence of the vector *Aedes aegypti;*
2. presence of the pathogen circulating in the population (dengue virus);
3. high density of the vector population;
4. longevity of the vector for the completion of the extrinsic incubation period of the virus;
5. a large immunologically naïve population; and
6. the non availability of vaccines.

To determine the presence of the dengue virus, sero-prevalence surveys of the population can be carried out. However, a major consideration has to be the cost of implementing the system. This is particularly important since dengue fever is classified as a Class II disease, i.e., not one of high priority, especially when compared with HIV/AIDS – even though in a 1981 outbreak in Cuba there were 10,312 cases of dengue hemorrhagic fever and 156 deaths (Uribe, 1983). Thus, a less expensive alternative to a campaign of sero-prevalence surveys is for the Ministry of Health to ensure that all diagnosed cases of dengue are reported.

Keeping in mind the element of cost and the need to be as simple as possible to encourage uptake, the early warning system that evolved was a checklist of indices to be monitored. The order in which surveillances are to be carried out or indices monitored are:

1. Climate surveillance for MAT Index;
2. Epidemiology surveillance for Breteau Index;
3. First reported cases of dengue below the epidemic level.[32]

[32] In the original project report, the system can be improved by the introduction of a third index, the pupae per person index. However this index required a level of technical expertise which would require more manpower and training that the Government of Jamaica was unlikely to fund at the time. For more information, see Focks and Chadee, 1997, and Focks et al., 2000.

The MAT index is the easiest to monitor. It simply requires data from an operational meteorological station. More costly epidemiology surveillance need not be carried out until the MAT index starts to indicate favourable conditions for development of disease within the vector and human populations. When this occurs, epidemiology surveillance, i.e., sending health inspectors into the field, can be put into place to improve environmental sanitation and to sensitize the population to the need for a clean environment. The level of alert can be increased once cases are reported.

The responsible surveillance agencies for the MAT index could be the national meteorological offices, which would provide temperature data, and the Climate Studies Group, Mona (CSGM), who would monitor the MAT index. The responsible agencies for monitoring the epidemiology indices and the reporting cases of dengue fever would be the Ministry of Health.

The epidemic response elicited would depend on the resources and policies of the government. Ideally there should be an infrastructure for climate and epidemiology surveillance and for ongoing evaluation and prevention. This combined system could provide the framework for risk analysis and vulnerability assessment, for issuing watch/warnings similar to storm and hurricane preparedness, and for developing response strategies. The system must also be capable of communicating effectively with the public and of soliciting feedback.

Leptospirosis

A recent project in the department of Physics, UWI, investigated the linkages between climate change and leptospirosis (Batchelor, 2010). Leptospirosis is a zoonotic bacterial infection which is usually spread to humans through water or soil that has been contaminated with urine from infected wild or domestic animals. In the Caribbean, there is also a climatic link between leptospirosis and precipitation. Storck et al. (2005) found a positive correlation between rainfall and the incidence of leptospirosis in Guadeloupe, while Brown (2004) found a high correlation with leptospirosis in the second rainy season of Jamaica.

Spectral techniques such as Fourier analysis have been used to find the relationship between diseases and climate variables but they fail to take into account non-stationary characteristics. For this reason, wavelet analysis is becoming increasingly popular to capture the non-stationary features of signals by observing the dominant frequencies as a function of time. Cazelles et al. (2005) used this approach to demonstrate the synchrony between dengue fever in Thailand and the NINO 3 climate index. It was again used by Chavez and Pascual (2006) for describing the dominant modes of cutaneous leishmaniasis incidence in Costa Rica and providing evidence of association to climate variability.

In the Jamaican analysis, data of reported cases of leptospirosis were obtained from the Ministry of Health and climate data (including maximum temperature, minimum temperature, and precipitation) were obtained from the Climate Studies Group at The University of the West Indies (Mona Campus), as well as from the website Climate Explorer.
The results computed show five major areas which have a significantly high correlation with rainfall. In the dataset are six episodes of El Niño which repeats between three to five years. For this reason, there could also be a correlation with leptospirosis and El Niño events in Jamaica (Batchelor, 2008).

Other Research on Diseases and Climate Variability

Amarakoon et al., (2004) provides details on the nature of association of diseases (dengue, asthma, bronchitis, respiratory tract infections, diarrhoeal illnesses) with climate variability, by studying the patterns of the diseases and investigating the degree of correlation between the diseases and climate parameters (temperature, rainfall, relative humidity, Sahara dust). The countries studied were Barbados and St. Lucia. Results indicated that the diseases considered exhibit a seasonal pattern. Occurrences are more likely in the latter part of the year (warmer) and extend to the early part of the following year (cooler). Disease patterns exhibit association with climate parameters. Dengue shows association with temperature and rainfall; respiratory diseases (asthma, bronchitis, respiratory tract infection) show association with temperature, relative humidity, and Sahara dust; while diarrhoeal illnesses with temperature and rainfall.

A common feature observed was that climate parameters appear to exhibit a positive correlation with the diseases after a certain lag. The influence of temperature appears to be the strongest. In the case of respiratory diseases, Saharan dust was believed by some to be a primary trigger but the low occurrence of asthma, bronchitis, and respiratory tract infection in summer, when Sahara dust concentration is high, may be suggesting that seasonal weather changes are dominating in triggering the diseases. Also to be noted is that Sahara dust correlates well with temperature. Further, the influence of other triggers such as local dust, pollen, smoke and ground level ozone cannot be ignored. Researchers in Trinidad and Tobago also reported a correlation between paediatric admissions for asthma and increasing Saharan dust cover (Gyan, et al., 2005, McCarthy, 2001).

Amarakoon et al. (2004) noted that the results were based on a limited amount of health data (2000-02) and that an in-depth study is required, with longer time series of health data, to reinforce and validate the observations, especially for respiratory diseases. Also, due to a lack of data, no attempt was made to examine the influence of various triggers: pollen, local dust, smoke, and ground level ozone on respiratory diseases. Based on the trends observed in climate parameters, possibility exists for the South Eastern Caribbean to experience higher incidences of dengue, respiratory diseases and Diarrheal illnesses in the present century.

Other Threats to Health

Health and well being depend on ecosystems and the services that they provide – food, water, and regulating, supporting and cultural services. The Millennium Assessment (2005) classified climate change as one of the direct drivers of change, presenting threats to health either indirectly through its effects on services or directly through its influence, for example, on vectors of diseases. Based on the analysis of vulnerabilities and the projections of climate change in Jamaica, the following health threats induced by climate change are possible in Jamaica.

Threat from droughts and higher temperatures: **Drought and high temperature can affect health indirectly through the loss of food production and subsequent necessity to import food and/or suffer food shortages, which may lead to hunger and malnutrition. Drought can also impact on the availability of potable water which can result in poor sanitation and the spread of disease. A reduction in rainfall leads to low river flow reduced effluent dilution and increased pathogen loading. Droughts may also lead to an increase in the abundance of mosquitoes since the amount of water storage in containers may increase with droughts, thereby providing suitable habitats for the mosquitoes. As noted earlier, this would have a direct impact on dengue fever transmission and that of malaria if present.**

While dengue fever has been discussed in some detail in this report, the impact of climate change on malaria is unclear and subject to much controversy. Analyses of time-series data in some sites in East

Africa indicate that malaria incidence has increased in the apparent absence of climate trends (Hay et al., 2002; Shanks et al., 2002). The malaria resurgence was attributed to factors including drug resistance of the malaria parasite and a decrease in vector control activities. However, the validity of this conclusion has been questioned because it may have resulted from inappropriate use of the climatic data (Patz, 2002). On the other hand, analysis of updated temperature data for these regions has found a significant warming trend since the end of the 1970s, with the magnitude of the change affecting transmission potential (Pascual et al., 2006). Malaria was almost completely eradicated from the English-speaking Caribbean since the mid-twentieth century, but increased illegal transit by fishermen to Haiti, where malaria is endemic, poses a serious threat to Jamaica.

Temperature increases may increase the altitudinal range of a number disease carrying mosquitoes and may affect communities in upland areas that are now outside the range of these mosquitoes. Higher temperatures may also be associated with increased episodes of diarrhoeal diseases and increase dangerous pollutants. In the first place, pollutants will be transported further due to greater mixing of the air. In addition, ozone concentration increases when nitrogen oxide and volatile organic compounds (produced from automobiles) react in the presence of bright sunshine with high temperature. Exposure to elevated concentrations of ozone is associated with increased hospital admission for pneumonia, chronic pulmonary disease, asthma, allergic rhinitis and premature mortality

Higher temperatures may cause greater contact between food and pest species, especially flies, leading to the spread of diseases

Warmer seas may contribute to toxic algae bloom and increased cases of human shellfish and reef-fish poisoning (ciguatera). Such cases have been reported in French Polynesia.

Projections for industrialized countries show that heat-related morbidity and mortality is projected to increase. However the burden of heat-related mortality is reduced when acclimatization and adaptation are taken into account. Thus the effect on tropical countries, such as in the Caribbean, would probably be small

Finally, changes in temperature and precipitation are also projected to increase the frequency and severity of fire events – causing burns and illness from smoke inhalation.

Threats from increased storm severity (category 5 hurricanes): While storms may decrease in frequency, severe hurricanes of category 5, with increased rainfall, have been projected to increase under at least one model. This would lead to severe flooding and loss of habitat. It would also increase the risk of water-borne and rodent-borne diseases such as typhoid and leptospirosis. In addition, increased flooding and structural damage in coastal regions due to storm surges will be compounded by sea level rise.

4.4.5 Proposed Elements of an Health Adaptation Strategy for Jamaica

A Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis (Table 4.25) was undertaken based upon the threats to human health posed by scenarios of future climate change and the state of readiness of response agents such as the Ministry of Health, Ministry of Agriculture, Office of Disaster Preparedness and Emergency Management, National Environmental Planning Association, National Water Commission, Water Resource Association, Forestry Department and the Meteorological Office.

The purpose of the analysis was to inform recommendations on adaptation strategies and a plan of action to prevent dangerous consequences of climate change to the health sector.
It is also noted that many recommendations of adaptation options emerging from the V&A assessments for agriculture, water resources, and coastal zones will have direct relevance to the health sector and are not repeated here. Instead, the focus is placed on the threat of increased incidence of dengue fever, since the approaches outlined could also be applied to other vector-borne diseases.

Table 4.25: SWOT Analysis of Adaptive Capacity of Health Sector in Jamaica to Climate Change

Strengths	Weaknesses	Opportunities	Threats
• Efficient health service by world standards. • Fairly good physical access to primary health care facilities. • Relatively high preparedness for disaster, although not for climate change. • Some recognition that climate change will have implications for vector-borne diseases • With adequate information, those citizens who saw that the individual had a role to play in sanitation environmental upkeep also tended to play an active part role in vector control. • High level of willingness displayed by communities to work alongside the Government in eliminating mosquito breeding habitats. • Good working relationship among organizations involved in disaster preparedness	• The health system is under resourced. • Inadequate fit between health services provision and needs of elderly • No regular epidemiology surveillance, shortage of manpower, equipment, supplies • Inadequate laboratory facilities • Privileging technological intervention over community development. • Inadequate sampling of water quality, shortfall in finances. • Link between climate change, agriculture and health not sufficiently appreciated. • Link between extremes in weather, disaster preparedness and health not sufficiently appreciated. • Inadequate provision for hurricane shelters.	• Take advantage of 2030 development plan to mainstream climate change into all sectors and policies. • Increase efforts to reduce poverty. • Reorganize health services to meet the needs of the elderly. • Place emphasis on community development – better sanitation, water supply • Educate population about the impacts of climate change, mitigation and conservation and environmental upkeep. • Include climate change issues in the mandate of response agencies. • Stimulate research on impacts of climate change on health. • Stimulate inter agency and intersectoral collaboration • Improve disease surveillance.	• Threat from droughts and higher temperatures, leading to food shortage, hunger and malnutrition. • Effect of water shortage, poor sanitation and the spread of diseases. • Threat of water storage practices providing habitats for mosquitoes and leading to increased dengue and malaria transmission. • Threat of temperature increases leading to increased rates of transmission of dengue and dengue hemorrhagic fever • Fish poisoning, polluted rivers. • Heat stress and its effect on an aging population. • Threat of air pollution, including ozone increases, and forest fires, leading to respiratory diseases

Strengths	Weaknesses	Opportunities	Threats
• Interest in research-based evidence within the Ministry of Health. • Extensive study of relationship between climate and dengue fever. • Adaptation strategies have been proposed • Declining poverty levels. • Benefit of CARICOM's projects and strategies	• Inadequate provision for children in shelters. • Absence of planning for sustainable tourism development' • Climate change not mainstreamed in health policy. • Lack of knowledge of cause and symptoms of dengue among population, • Lack of appreciation of the seriousness of dengue hemorrhagic fever among the population. • Most residents in vulnerable situations see vector control as a responsibility of Government. • Too little attention paid to public education • Insufficient interagency and intersectoral collaboration.	• Implement early warning systems for dengue and other vector borne diseases. • Options for diversification of tourism product.	• Threats from increased storm severity leading to flooding, loss of habitat, increased risk of water-borne and rodent-borne diseases, such as typhoid and leptospirosis. • Increased incidence of diseases in shelters following disaster • Lack of worldwide emphasis on mitigation of greenhouse gases, especially in USA and Canada.

In Table 4.26, a matrix of possible adaptation options is described for coping with an increased threat of dengue fever. The methods listed include those currently employed in the Caribbean region, options practiced elsewhere in the world or on a very limited scale within the region, and options that present themselves as future (though not too distant) possibility as a result of ongoing research in the region.

Table 4.26: Adaptation Options for Coping with Increased Threat of Dengue Fever in Jamaica

Recommendation	Justification	Responsibility	Workshop Pooled Ranking
	sector, yet it is important for food security and rural incomes, and to provide funds to allow these producers to adapt to climate change This will lead to the empowerment of domestic producers.	PIOJ, Funding and financial agencies.	
7. Leverage and co-ordinate international funding to maximise benefits within the Agricultural Sector	Significant investment is required in a number of areas within the sector. If multi-lateral grant-aid & bi-lateral soft loans are to be used to support this work, then the benefits accrued must be maximised, both in outputs and capacity building.	Ministries of Agriculture and Land and International Trade, Finance and Planning, PIOJ.	1
8. Support & fund increased water use efficiency across irrigated agriculture	Improved water use efficiency will reduce demands on existing sources and infrastructure, reduce costs and reduce vulnerability to drought.	NIC and other Ag. water providers and consumers	5
9. Initiate Climate Change Working Group for Agriculture	There is a need to co-ordinate efforts across the sector, to provide focus and direction for research & policy development including a global focus on world market trends on food production and food security	Ministry of Agriculture & Lands to lead supported by Research Institutes, Industry bodies.	8
10. Review role of financial instruments to provide insurance protection to key sub-sectors	Access to insurance products may provide one method of adaptation to key sub-sectors, although their operation and expense must also be considered under climate change	Ministries of Agriculture and Land, Finance and Planning, insurance agencies and brokers, farmers organizations.	10

The options are assessed on six characteristics which are rated high, medium and low. For example, cost is a serious adaptive constraint and so each proposed adaptation option is rated on the likely cost of implementation within the context of the Caribbean region. The assessments are based on expert opinion and are guided by the responses on questionnaires administered to the attendees of the end-of-project workshops. They therefore reflect the considered views and knowledge of the region's environmental health officers. The assessment characteristics were:

i. Cost of implementation;
ii. Effectiveness (as measured by its long-term ability to reduce risk or address vulnerability);
iii. Social acceptability;
iv. Environmental friendliness;
v. Promotion of neighbourliness; and
vi. Technical and/or socioeconomic challenges to implementation.

A simple composite score is offered in the final column for comparison purposes. In compiling the score, high is given a score of 5, medium a score of 3 and low a score of 1, except for categories (i) and (vi) where the scoring allocation is reversed. The maximum possible score is 30. The strategies fall under the three main headings of: 1. health education and promotion, 2. surveillance, and 3. adult and vector control. They are also divided into short-term and long-term practices, i.e., whether their intent is to immediately alleviate the threat associated with dengue fever or to do so gradually.

Table 4.28: Adaptation Options for Coping with Increased Threat of Dengue Fever in Jamaica

MEASURES	Cost	Effective-ness	Social accept-ability	Friendly for environ-ment	Neigh-bour effects	Technical challenges and socio-economic change	Score
Short Term							
1. Adulticide (ULV or thermal fog sprays) in truck or air	H	L	L	L	L	H	6
2. Education (disease symptoms, sanitizing the environment).	M	M	H	H	H	M	24
3. Surveillance for vector or larval/pupal control.	H	M	M	M	M	L	1 8
Long Term							
1. Surveillance for vector or larval/pupal control and environmental sanitation	H	M	M	M	L	L	16
2. Community education and involvement.	M	H	H	H	H	M	26
3. Chemical control	H	M	M	L	M	L	16
4. Biological control	H	H	M	H	M	M	20
5. Adult Control							
- Physical – mesh windows	M	H	H	H	H	H	24
- Personal protection	M	M	M	M	M	H	16
6. Use of physical control-low cost secure drums	H	H	M	H	H	H	20
7. Granting security of tenure to squatters	H	H	H	M	H	H	20
8. Early warning system	M	H	H	H	H	H	24

Columns 2 through 7 indicate assessment criteria. Column 8 gives a composite score based on the ranking in columns 2-7. Assessments are on the basis of High, Medium, and Low. In compiling the composite score, High is given a score of 5, medium a score of 3 and Low a score of 1, except for columns 2 and 7 where the scoring allocation is reversed. The maximum possible score is 30.

The short-term strategies are those currently adopted in the region, namely: public education aimed at encouraging individuals to identify and eliminate current breeding sites and to identify dengue symptoms; surveillance in outbreak communities for the purpose of environmental sanitization; and adult mosquito control through the use of an appropriate insecticide (fogging). Of the three, public education achieved the highest composite score while fogging achieved the lowest score. Education benefits from the fact that in the present framework it is generally medium to high ranked in each category. Its effectiveness is medium-ranked due to the seasonal nature of the campaign, while the presence of established units to handle education accounts for the medium (as opposed to high) ranking with respect to cost and technical challenges. Insecticidal fogging, though oft demanded and practiced, suffers from limited long term effectiveness, an inability to promote neighbourliness (people shut their windows), and limited social acceptability as the often used insecticide – malathion – has a characteristically unpleasant odour, and there is the need for specialized equipment for its distribution.

Of the long-term strategies assessed, education strategies again achieved the highest composite ranking (though only marginally so), with the focus being on sustained campaigns aimed at community education (as opposed to targeting individual behavioural practices) and community involvement. Chemical control, surveillance practices, and strategies relying on the individual to personally protect themselves received lowest scores. Surveillance as a long-term approach does not engender neighbourliness (general suspicion), while the best personal protective measures come at a cost to the individuals, thereby limiting their possible use by the poorest who are the most vulnerable.

Generally, however, most strategies fall in the mid-range of scores (16–24), suggesting that relative advantages in one area are offset by disadvantages in other areas. Physical control via the use of low cost covered drums would address vulnerability issues surrounding water storage, but such drums or drum covers are yet to be designed and would have to be subsidized or made available free to the most vulnerable. Even then, much would depend on householders being vigilant in covering containers. Granting security of tenure to squatter individuals would promote community structure and increase the possibility of the eventual implementation of appropriate infrastructure for regular water supply. Such a move, however, is costly and fraught with social tensions. Biological control, e.g. using fish to control mosquito population is an environmentally friendly option, but is not suited to community practice unless the community could be persuaded of the benefits of proper implementation. Finally, using an early warning system for action would imply the coordination of a number of agencies (e.g. climate research and monitoring agencies and the health ministry) and the development of appropriate thresholds for action and coordinated action plans.

<u>Best Practice Recommendations for Addressing Dengue Fever</u>

No single "best" adaptation option exists to counteract the threat of increasing dengue fever within the Caribbean. As suggested by Table 4.28 the variety of strategies has their relative merits and demerits. In light of that, three adaptation options are offered as possible ways of approaching the problem. Each option represents a combination of selected strategies outlined in Table 4.21, with due consideration given to their relative strengths and weaknesses. The options also give primacy to the need to address the issues of vulnerability, namely the lack of knowledge about dengue fever, the lack of community structure to facilitate collective action, and the issues of water storage. The options increase in human and economic investment required and all assume that the currently practiced strategies outlined are at least maintained.

Option 1 – Refocusing Current Strategies: Option 1 advocate that currently employed strategies are maintained at least at their present level of activity and funding, but that approaches to them be refocused, and relatively minor modifications be made. Education is emphasized as the lynchpin of this option with, however, a slant towards the personal and community good that would derive from the environmental sanitation and vector control strategies proposed in the campaign. This is as opposed to merely providing information about the disease and the steps to be taken to reduce mosquito abundance. A proposed modification would also be to engage communities prior to the rainy season through organized activities in nearby churches, schools, youth and service clubs and utilizing competitions to test knowledge and community cleanliness. Involvement prior to dengue onset would promote long-term behavioural change (not just a dengue season problem) and community responsibility. Vector surveillance in its current form would provide support for the educational activities, particularly approaching the dengue season.

Option 1 would call for the least additional investment, though an upgrading of the capacity of the education and promotion units of the health ministry to initiate and sustain activities outside the dengue season would be required. The possibility of cost sharing with the engaged community groups should also be explored.

Option 2 – Adding Proper Water Storage: Option 1 does not address the vulnerability issues surrounding proper water storage. The proposed adaptation strategies (design of drums and covers and security of tenure) are costly, however, and consequently requires greater investment by the Ministry of Health.

For Option 2, the refocusing actions of Option 1 are still undertaken as they address education deficiencies and community involvement and responsibility. In addition, however, the design of a suitable low-cost water storage drum or drum cover would be actively pursued. Currently, water is stored in discarded 'oil' drums which are left open to catch water running from rooftops when it rains. The open nature allows for the breeding of the vector. A unit which allows water in, with a cover is easily removable but secure, or from which water can be easily removed otherwise is the ideal. The option to design a drum cover that meets the latter characteristics also exists as the storage drums commonly utilized are fairly standard in size. Such units/covers do not exist currently and might be costly to design and manufacture with little guarantee of their eventual use by the community. To ensure the latter, incentives would have to be offered, e.g., subsidies and an intensive public education emphasizing the value of the drums/drum covers. Incentives may also have to be given to cover the drums, despite the presence of the drum covers, while efforts would also have to be made to ensure that other habitats are made vector-free.

Option 3 – Adding an Early Warning System: Like Option 1, an early warning system has the advantage of anticipatory action. However, whereas Option 1 promotes education simply based on the knowledge that there is a dengue season, an early warning system attempts to gauge the severity of any possible outbreak. Consequently, enhanced or diminished responses can be made on the basis of the anticipated level of threat. Option 3 therefore proposes the actions of Option 1, but coupled with an early warning system. As discussed earlier, monitoring of climatic indices would be undertaken by the Meteorological Service, regional universities and/or regional climate research institutes. On this basis, the frequency of surveillance would be altered and the education campaign tailored to meet the level of perceived threat. If surveillance data confirm the presence of the pathogen or an increase in its abundance, subsequent warnings could be issued as needed. A benefit of this multi-staged early warning approach is that response plans can be gradually ramped up (e.g., the inclusion of other strategies such as chemical or biological control) as forecast certainty increases. This would give public health officials several opportunities to weigh the costs of response actions against the risk posed to the public.

The implementation of Option 3, however, requires a memorandum of understanding between the cooperating institutions, a definition of roles, a focal point, some investment in research, and the possibility of staging of a pilot project.

Additional Recommendations for the Ministry of Health

- The public should be educated about ways of handling heat stresses; taxes on electric fans should be eliminated to encourage persons less well off to purchase them, although this would not be the direct responsibility of the Ministry;
- Public education in the area of sanitation and food poisoning need to be increased and steps taken to be prepared for increases incidents of food poisoning;
- Public health inspection for mosquitoes should increase, even at higher elevations such as Mandeville and Christiana;
- Pest and rodent eradication should be improved.

Additional Recommendations for Ministry with Responsibility for Housing

House designs are strongly influenced by styles that are more appropriate for temperate living. Sustainable design standard are needed for housing in areas subjected not only to year-round high temperatures that are projected to increase, but also to high rainfall and strong hurricane winds. Roofing material used in the island can increase heat absorption and retention and increase thermal stress. Modern designs are replacing the louvered windows that increase ventilation. The elevation of houses would also increase ventilation and reduce the risk of flood damage in low lying areas. These changes would help address impacts of heat stress and effects of disasters on human health.

More attention should be paid to the design of settlements to reduce those aspects that would result in the amplification of vector borne diseases.

Priorities

It is recognized that the recommendations stated above are for an ideal situation, but funding may not be available for all needed actions. Priority should be given to:

(i) Options for adapting to increased incidence of dengue fever, particularly the design of suitable drums for water storage and for an early warning system based on the MAT and Breteau indices;

(ii) Better water monitoring and management through improvements in the National Water Commission and the Water Resources Authority to reduce risks of water-borne diseases;

(iii) Improving the capabilities of the Office of Disaster Preparedness and Emergency Management to warn of, and react to, disasters;

(iv) Improving the data gathering ability and technical and support staff of the Meteorological Office since parameters such a temperature, air quality and flooding are related to human health;

(v) More collaboration between research institutions and national agencies involved in dealing with health and climate change issues.

Even if the dangerous climate change scenarios do not materialize, these measures would be in the best interest of the nation, i.e., they would be ‘no-regrets’ adaptation options.

4.4.6 Constraints of the Health Sector V&A Assessment

Uncertainties related to health and climate change studies could be reduced with improved data and modelling. All available climate data from national sources, such as sugar plantations, private weather stations, national weather stations, public works agencies, etc., should be collected and subject to quality control so it can be used to validate regional models and calibrate statistical models. Support should also be given to research institutions to run as many regional and statistical downscaling models as possible for calibration and inter-comparison purposes in order to reduce uncertainty.

The true cost of the impact of climate change on the Jamaican economy with respect to the health sector is unknown. A cost benefit analysis should be conducted to determine these costs.

A design for a safe storage drum which will store potable water free of mosquitoes is not available. Incentives should be provided to encourage the design of such a drum.

An early warning system for dengue fever is not available. The mechanisms for the operation of an early warning system for dengue fever should be put in place.

4.5 The Coastal Resources Sector, including Human Settlements

Five areas were selected for V&A studies based on a variety of features which, collectively, characterize much of the Jamaican coastline. Both bio-geophysical and socio-economic factors were considered. From these studies, a coastal vulnerability index was prepared and adaptation options identified.

4.5.1 Main Characteristics of the Coastal Zones Sector in Jamaica

Oceanography

A micro-tidal regime exists along most of Jamaica's coastline, the tidal range being about 30cm with spring tide ranges up to about 45cm. The direction of travel and the height of incoming waves are primarily governed by the Trade Winds, so that most wave trains arrive from the northeast, east and southeast. These are refracted around the various headlands, so that along the north coast wave sets arrive dominantly from east to northeast, whereas on the south coast the waves come from the southeast. Winter weather systems ("northers") are generated by high pressure build-ups over the North American continent. As a result, winter wave trains may arrive at the north coast from a north to north-westerly direction. At this time, conditions along the south coast tend to be relatively calm.

Conversely, in the summer it is the north coast that stays relatively calm while the south coast may suffer for extended periods from rough seas generated by the Trade Winds, because the length of fetch extends across the Caribbean Sea. Based on offshore buoy data from south of Jamaica, this creates significant wave heights in the Jamaican region around 1.6m (Table 4.29).

Table 4.29: Data (mean values) from NOAA Buoy 41018 (August 1994 to January 1996)

Wind speed (m/s)	7.79
Wind direction (deg.)	90.93
Significant wave height (m)	1.63
Wave period (s)	5.19

Source: Adapted from Calverly et al., 2001

As might be expected, the prevailing currents also flow from east to west. Figure 4.21 indicates the main pattern in the Jamaican region; more barbs indicate stronger flow (see also NRCA, 1997a). Along the central part of the south coast, these 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). The reasons for the sporadic sand movement are not fully understood but are probably related to flood events in the Rio Minho.

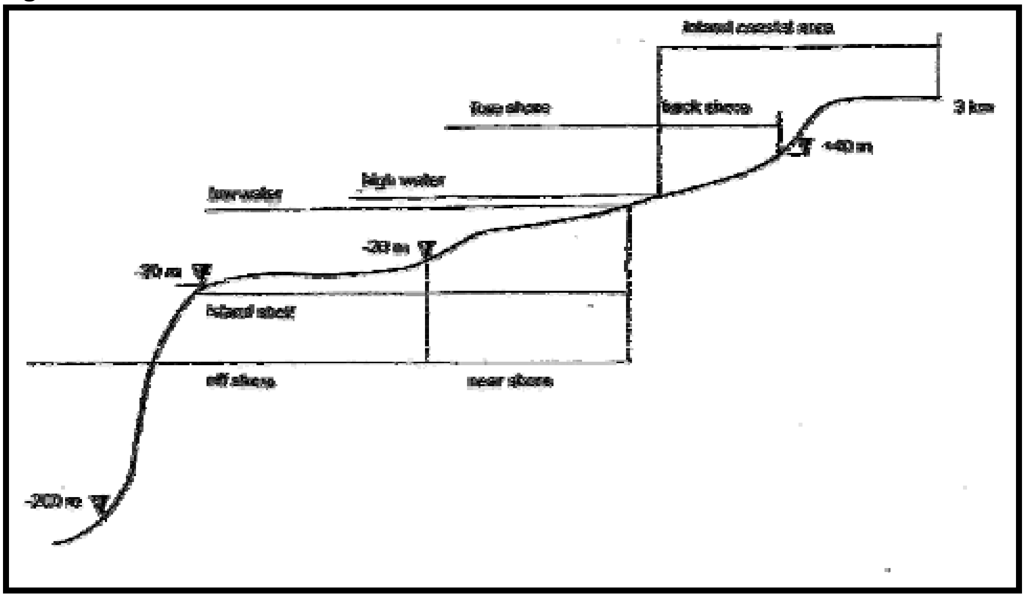
Figure 4.21: Ocean Current Regime near Jamaica for the Month of July

Source: Wust, in Emilsson, 1971

Defining the Coastal Zone of Jamaica

Defining the coastal zone is a complex exercise, presenting many challenges. It may be simply defined as that transitional area between the land and sea, but the nature, size and shape of its boundaries depend on several criteria that relate to the resources within the zone and the geographical factors of importance for each segment of the coast. Natural factors might include the extent of typical coastal vegetation, physical features such as beaches and wetlands, the presence of coral reefs, width of the island shelf. Human factors include coastal-dependent industries, settlement patterns, aesthetic and recreational features, and management and administrative factors. The coastal classification scheme used for Jamaica in the National Coastal Atlas (NRCA, 1997) is the only scheme published for Jamaica (Figure 4.22).

Figure 4.22: Illustration of Different Coastal Boundaries of Jamaica



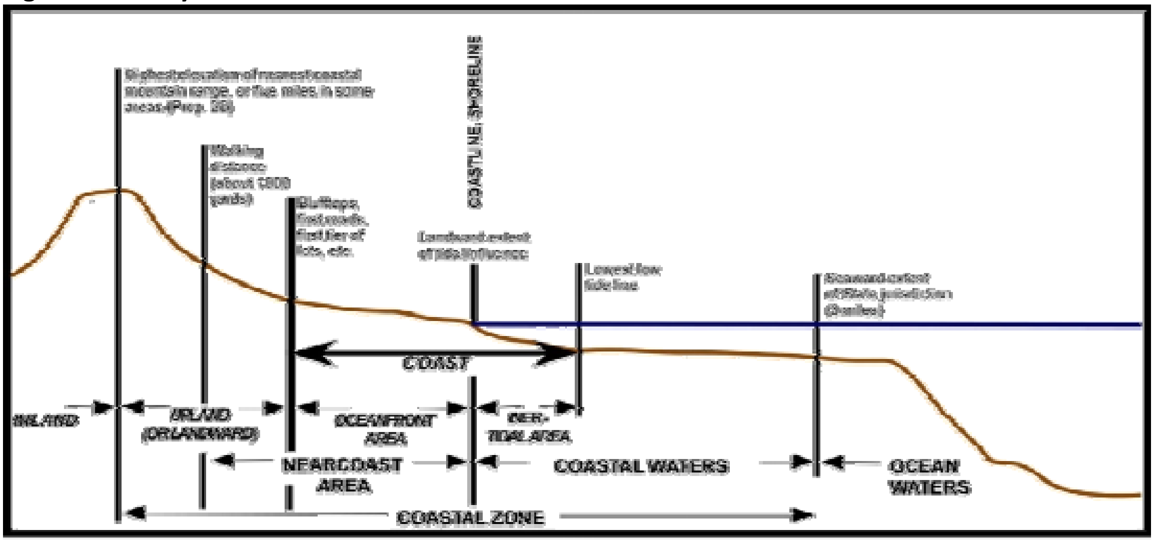
Source: NRCA, 1997

The following definitions are used in the Coastal Atlas:

- 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 *Nearshore 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.

Figure 4.24 further indicates the physical features characterizing the coastal zone as suggested by UNEP (redrawn from Trumbic, 2008).

Figure 4.23: Physical Features that Characterize a Coastal Zone



Exaggerated vertical and horizontal scales

The coastal area and coastal zone, according to UNEP (1995, 52).

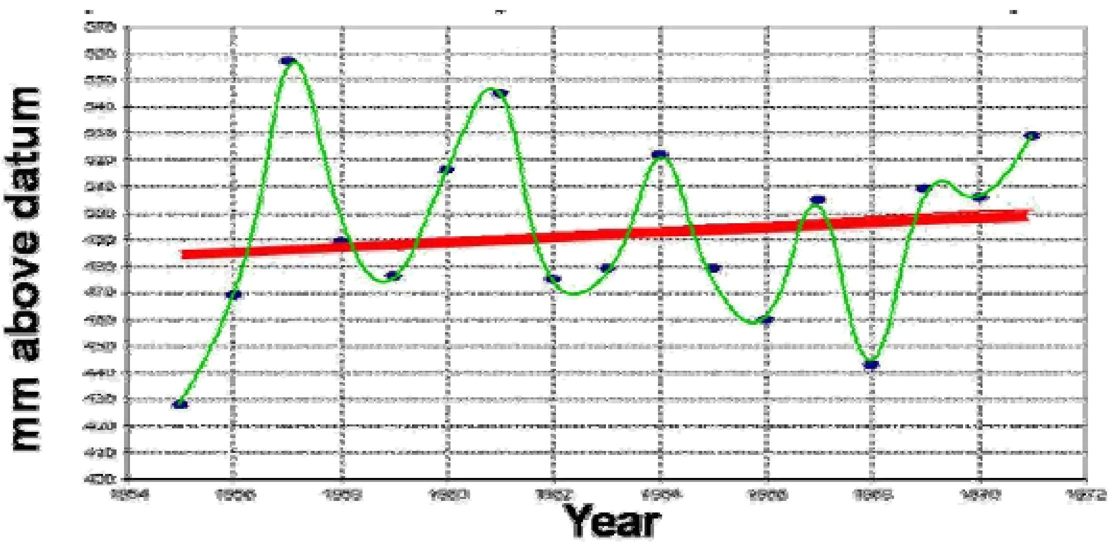
For this assessment, physical aspects of the coastal zone were defined for each of the five study areas, with emphasis being placed on the following factors:

- The **Backshore Area** is defined (where applicable) by the highest topographic features behind the coastline, following the UNEP definition. This area then encompasses the storm gully systems that reach the coastline and includes all wetlands behind the coastal beaches.
- The **Principal Hazard Area** is defined by the region between the 7.6m (25 ft) contour drawn on most of the 1:12,500 scale topographic map series of Jamaica and the shoreline (mean high water mark, or MHWM). This effectively delineates those areas near the coast that could be affected by unusually large inundations caused by hurricane storm surge or tsunami. Although it is not expected that flooding on that scale will be frequent or extensive, the delineated zone provides a focus for examining features that may be vulnerable to varying degrees. Figure 4.24 shows the extent of the Principal Hazard Area for the Jamaican coastline.
- The **Island Shelf Area** encompasses the region between the shoreline and the outer edge of the island shelf. The zone below MHWM is under the legal jurisdiction of the Beach Control Authority. The depth of the shelf edge is not fixed but varies from place to place, from about 12m to some 35m. It is consistently characterized by the more or less abrupt change of gradient marking the top of the island slope into deep water. The width of the island shelf varies from less than half a kilometre to as much as 35km along the central part of the south coast (roughly delineated by the 100m isobaths on Figure 4.31. In practice, the floats of fish pots commonly used by the local fishermen frequently indicate the extent of the island shelf.

Figure 4.25: Map of Jamaica, showing Principal Hazard areas (below 7.6m) in red

An accurate local assessment of MHWM is difficult to define in Jamaica owing to the absence of a working tide gauge and long tide gauge records. The survey datum for land elevations is Mean Sea-Level (MSL), determined from tide gauge readings at Port Royal over the 17-years from 1956 to 1972 (pers. comm. Calvin Thompson, National Land Agency; 2008). The mean annual sea levels are shown in Figure 4.25. The wavy green line is year-to-year fluctuation in mean annual sea-level; the straight red line is the overall trend. The largest year-to-year fluctuation is 8.8cm, the smallest is 0.3 cm. The overall trend shows a rise of about 1.5cm. Some of the problems associated with defining a local sea-level that can be used as a basis for projecting future sea-level changes are addressed in Byrnes et al. (2003).

Figure 4.26: Mean Annual Sea-Levels at Port Royal (1955-71)



Source: Modified from Horsfield, 1973

Ownership

In Jamaica, private ownership is supposed to terminate at the high-water mark. The main problem revolves around the definition of the shoreline and the high-water mark, now and into the future. The position of high-water mark varies with tides, with seasons, from year to year, with sea level rise (or fall), with beach erosion or progradation. In practice, ownership is effectively defined by the position of high-water mark on the date the property boundary survey was made.

4.5.2 General Impacts of Climate Change on the Coastal Zone Sector

Sea-level Change

The effects of changes in sea-level on any particular coastline depend on the geological and geomorphological characteristics of that coastline, including sediment supplies, and the extent to which coastal features have been modified by human activities.

It is generally accepted that sea level is rising, and that this rise will continue into the foreseeable future. The most recent internationally researched publication (IPCC, 2007) suggested, conservatively, that the rise between the present (1980-99) and the end of this century (2090-99) would be about 0.35m (0.21-0.48m) for the A1B scenario and 0.26-0.59m for the A1F1 scenario (IPCC, 2007, see Section 10.6). Table 4.30 (simplified from IPCC, 2007) lists projected rises for a number of scenarios by the year 2100).

Table 4.30: 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

Source: Adapted from IPCC 2007, Table TS.6

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). Therefore projected global average rates are used in this report.

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).

Table 4.31, based on examination of the IPCC (2007) projected curve and a similar curve constructed by Rahmstorf (2007), suggests likely annual rise rates for the present day (2008), and for the years 2015, 2030, 2050, and 2100. In both cases, the high side of the curve envelope was used. The two projection sets contained in Table 4.29 were used for this V&A assessment. It should be emphasized that the relative importance of contributing factors to sea-level rise (e.g. IPCC 2007, Table 10.7) and hence the reliability of these projections, is currently a matter for considerable debate and controversy.

Table 4.31: Approximate Rates of Sea-Level Rise Projected For Four Future Time Slices (2015-2100)

	2008	**2015**	**2030**	**2050**	**2100**	**Unit**
Rate (IPCC, 2007; high side)	2-3	3	3.8	4.8	6.1	MM/YR
Cumulative amount	0	23	81	173	451	MM
Rate (Rahmstorf, 2007; high side)	2-4	5.7	7.3	11.3	22.2	MM/YR
Cumulative amount	0	28	122	313	1168	MM

Source: Derived empirically from the high side of the envelopes of estimates published by the IPCC (2007) and Rahmstorf (2007)

Research on the future dimensions of rising sea level (IPCC, 2001, 2007) suggests that the current rise will continue at least until there is partial or complete melting of the world's smaller ice caps and the Greenland ice cap. Together with thermal expansion of sea water, this will eventually produce a sea level rise of up to 6 metres, that is, within the 7.6 m (25 ft) contour.

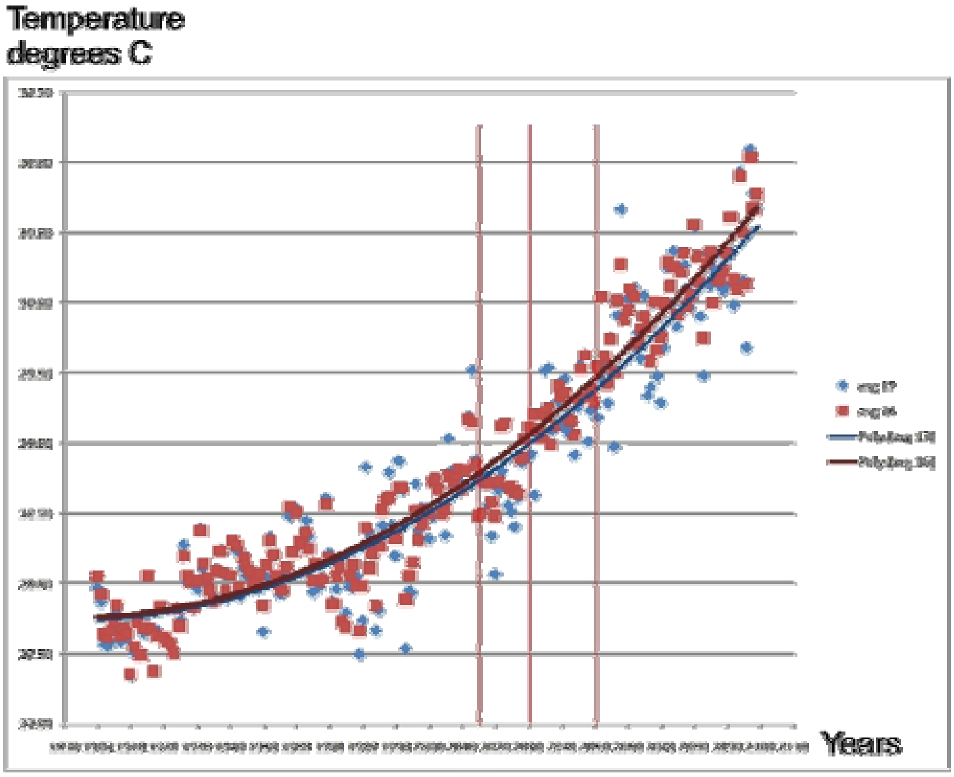
<u>Sea surface temperatures</u>

Projections of sea-surface temperatures have been made for the Caribbean by Sheppard & Rioja-Nieto (2005). A graph based on data from Sheppard & Rioja-Nieto is shown in Figure 4.26. Vertical bars in the figure indicate the years 2015, 2030, and 2050 respectively. Avg. 16 and 17 refer to the two data cells closest to Jamaica.

In examining the effects of sea-surface temperature rise on reef systems, the following quote provides an apt commentary pertinent to the Jamaican situation (from Hallock, 2005):

> "Hoegh-Guldberg (1999) reviewed the coral-bleaching literature, examined global climate models, and predicted that summer sea-surface temperatures high enough to induce coral bleaching will become nearly annual events on reefs worldwide over the next several decades. Realistically, coral populations cannot survive annual bleaching. If global-warming models are even close to accurate, bleaching could eliminate shallow-water coral reefs within a few decades."

Figure 4.26: Graph of Sea-Surface Temperatures for the Jamaican Region



Source: Compiled from data downloaded from Sheppard & Rioja-Nieto (2005)

<u>Changes in Acidity (pH)</u>

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 realized, 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).

<u>Severe Weather Events</u>

Since 1980, Atlantic hurricane counts and the power dissipation index (PDI) have increased considerably, along with increases in sea surface temperatures. Controversy continues over whether or not the projected increases in sea surface temperatures will lead to a continued increase in storm frequency (IPCC, 2007). There is more general agreement that there may be an increase in the frequency of severe hurricanes. Recent investigations suggest that hurricane-generated wave heights along the eastern seaboard of the US and eastern Caribbean have been increasing (Komar & Allan, 2008; Halcrow, 1998). However, historical studies suggest the ~~current~~ relatively high frequency of storm events in the first decade of the 21st Century is probably cyclical, as much related to variations in El Nino cycles and wind shear as to global warming (Donnelly & Woodruff. 2007; Nyberg, et al., 2007).

Recent dynamical modelling (Knutson et al. 2008; Vecchi & Soden 2007) suggests that the frequencies of Atlantic hurricanes and tropical storms may even be reduced by the end of this century, although near-storm rainfall rates should increase substantially as well as the incidence of very intense storms. For the purposes of indicating the likely future effects of hurricanes on the Jamaican coastline, it was chosen to use data from return period modelling based on frequencies at the time of the assessment, unchanged, when examining the effects of future severe cyclonic weather events.

Flooding

Flooding in the coastal zone can arise from severe weather events, such as hurricanes, that result in storm surges and flooding from the sea, as well as intense rainfall that may result in riverine floods, debris floods, or flows along coastal gullies. In the worst case scenario, flooding from the sea surge and run-up from a severe hurricane, added to a high spring tide, coincides with extreme rainfall resulting in riverine and gully flooding. The surge and tide causes backup of the riverine flood. Over the long term, sea-level rise will lead to gradual inundation of very low-lying areas, either from the sea or from the accompanying rise in the groundwater table, but such effects will tend to be masked by the consequences of flooding from severe weather impacts.

Rare events such as seismic sea waves (tsunami) will also inundate the coastline to varying extents, depending on the energy level of the event. While tsunamis are not directly related to climate change, the flooding effects will become more severe as sea-level rises. Tsunami events in the Jamaican region are discussed in Ahmad (1998), Robinson *et al.* (2005a, 2005b), Lander *et al.* (2002). No reliable return period estimates are possible for tsunami, but a review of the historical record for Jamaica suggests that tsunami have resulted from local seismic events and submarine slides rather than from more distant seismic and volcanic events. This means that warning times are likely to be very short, on the order of 10 minutes or less. These times are shorter than can be transmitted by the current Caribbean Tsunami Early Warning System.

4.5.3 Responses of the Coastal Zone

Coastal Erosion/Recession

Beaches

Shoreline retreat along sandy beaches is caused by various physical shoreline processes. Because of the complexity of the variables there is considerable controversy over the kinds of changes that will take place as sea-level rises (Gutierrez et al., 2007). Over short time-scales, storms are probably the dominant factor (Zhang et al., 2002). Over longer time-scales, variation in sand supply, the geological setting and sea-level rise become important (Zhang et al., 2002; Pilkey & Cooper, 2004). Where there is an adequate supply of sediment, a beach will change its position in space as sea level rises, migrating upwards and inland.

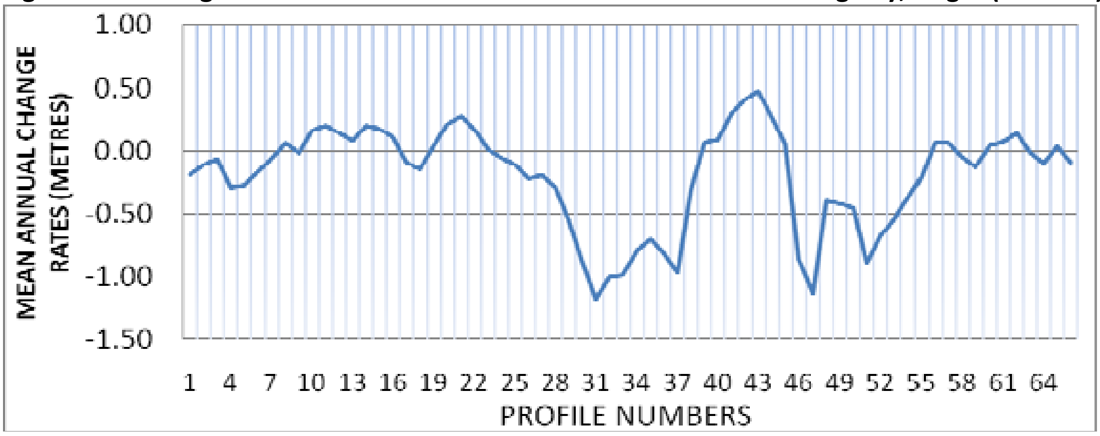
Vertical incision occurs (i.e., sea-level continues to rise but no shoreline retreat takes place) when the beach is constrained, either by rocky outcrops or by sea-walls and other anthropogenic structures, and an equilibrium profile can no longer be maintained further inland. If there is no development, the natural progression of sea level rise would result in the beach system incrementally transgressing over the sub-aerial part of the coastal zone. However, the presence of sea-walls, highways and other coastal structures will prevent this, and lead to increased vertical incision as hardened structures proliferate. The natural erosion of the beach region ceases, causing sand starvation to the beach profile. This will increase in severity unless fresh supplies of sand are available from near-shore or riverine sources. Even if appreciable long-shore drift takes place to supply new beach materials, the reduction in the availability of erodible shoreline deposits will likely still lead to progressive loss of beaches.

Sediment supply is different for the two main kinds of sand beaches in Jamaica:

- For **siliciclastic (dark sand) beaches** such as those at St. Margaret's Bay and Portmore, sediment is supplied via transport through river systems, usually during flood events, from the island's interior. Supplies necessary for the natural maintenance of such beaches depend on regular supplies from the hinterland. These can be reduced during periods of drought or by excessive removal of sand from the river bed by sand mining. This may be counterbalanced by increased supplies over time if deforestation leads to accelerated soil erosion in the interior.
- For **carbonate (white sand) beaches** such as those at Long Bay, Negril, and much of the St. James coastline, sand supplies are sourced from skeletal material manufactured by marine organisms living in the reef and back-reef areas, mainly calcareous algae, corals, and symbiont-bearing foraminifera, together with echinoids and molluscs. The maintenance of a healthy near-shore marine environment is essential for supplies to continue, as carbonate sand grains have a much shorter life span than the siliclastic grains of dark sand beaches, and degrade to mud from abrasion and chemical solution. The recent deterioration of Jamaican reefs systems (Hughes, 1994, see section on corals) threatens to severely curtail carbonate sand supplies at a time when sea-level rise is becoming more evident.

<u>Predicting Beach Changes.</u> Two methods are in widespread use in attempting to predict the rate at which a shoreline will retreat in the future, whether due to sea-level rise or to other shoreline processes. The first uses the evidence of past shoreline positions and sea-levels to estimate the possible locations of future shorelines (Crowell et al, 1999; Fletcher et al., 2003; Figure 4.27). The second uses the so-called "Bruun Rule" to calculate the positions of future shorelines, based on the concept that each particular beach strives to maintain the shape of its equilibrium profile as sea level rises (Masselink & Hughes, 2003). Both methods have their critics as well as their supporters (Dubois, 1975; Pilkey & Cooper, 2004).

Figure 4.27: Using Past Shoreline Positions to Predict the Future at Long Bay, Negril (1971-03)



Mean annual rates of shoreline change at Long Bay, Negril, over 32 years from 1971-03 plotted for each of a set of 67 measured shoreline profiles. Positive numbers indicate net accretion; negative numbers net recession. Note the erosion "hot spots" between beach profiles 26 to 38 and 45 to 55. Profile 1 is at southern end, profile 67 is at northern end of Long Bay.

Sand loss to the system. In a study carried out in the Virgin Islands (Hubbard, 1992), the passage of Hurricane Hugo on September 17, 1989, over St. Croix, over a shelf dominated by white sand, generated wave heights of 6-7m and caused wholesale flushing of sand from shelf edge areas into deep water. Eleven times the amount of sediment as is usually moved in fair weather was transported. The volume of sediment removed from the Salt River submarine canyon was approximately equivalent to the amount of sediment that would have built up in a hundred years. The storm surge was only 1.0-1.5 m because of the narrow island shelf in this area. Similar losses, especially of the increasingly hard to replace carbonate sand, are likely to occur along the coasts lined with carbonate beach sand.

Geological evidence, in the form of debris fans at the foot of reef complexes, in water too deep for natural recovery to take place, indicates that this is happening on a continued basis.

Cliffs and Rocky Coasts

Most of Jamaica's coastlines are cut in limestone cliffs; most commonly limestone generated within the past half million years as former coral reef systems, now elevated above sea-level. The most recently formed systems were built about 130,000 years ago. Cliffs cut in other kinds of rock, mainly sandstone, conglomerates and volcanic rocks, are located along the northeast coast between Port Maria and Annotto Bay, along parts of the coast of Hanover Parish, and at Black Hill in Portland Parish. These coastlines are formed of rocks that are for the most part well lithified. However, in fracture zones associated with faulting, these rocks are prone to solution along joints (limestone) and shattering, giving rise to coastal rock falls and landslides.

Figure 4.28: Housing on Cliff above Extensive Cliff Collapse, North Coast of Jamaica

Other cliffs may be cut in softer rocks and unconsolidated or poorly consolidated marls, as at Port Morant, St. Thomas Parish, gravels, as along parts of the St. James coast, and old sand dunes, as along the south coast of St. Elizabeth Parish at Great Bay and elsewhere. Cliffs of softer rocks will tend to suffer higher rates of erosion.

Figure 4.27: Medium High Cliff Cut in Easily Erodible Marls, Southeast Coast of Jamaica

Recession rates along cliffed coasts are usually much less than along beaches, but recession may occur suddenly as a collapse, so that care needs to be taken in building along such coasts. In addition, hurricanes can deposit large quantities of rock debris over the cliff tops along such coasts.

The effect of sea-level rise on cliff lines may result in deepening of the water at the cliff base, allowing higher energy waves to attack the cliff, possibly resulting in increased rates of recession. Whether or not this occurs depends on the availability of marine sediments to act as a buffer to wave attack.

Wetlands

Coastal wetlands are recognized as unique and vulnerable, but valuable habitats. By their very nature, they lie close to sea-level and exhibit a range of temperature and salinity variation, from salinities approaching that of the open ocean to freshwater, due to the varying influences of tides and drainage from the interior. They are widely recognized to be one of the most productive ecosystems, as well as buffering the effects of inundation from ocean surges due to hurricanes. Most wetlands are less than one metre above sea-level. The particular problems of wetlands have been described and discussed in the NRCA Coastal Atlas and Coastal Manual (NRCA, 1997a, 1997b).

The continued existence of coastal wetlands depends on maintaining a delicate balance between sea-level change, vertical accretion, and subsidence. Vertical accretion is attained partly by the influx of, usually, fine grained sediments from riverine floods, or sand deposited in the coastal margin of the wetland from surges, and partly through the growth and decomposition of the wetland vegetation. Subsidence results from the compaction of the decomposed organic material (to form peat) and any accompanying clay, possibly also through tectonic adjustments of the region. In Jamaica, which is dominated by a micro-tidal environment, the small range of the tide tends to promote relatively stable boundary conditions within the wetland. Thus the more saline parts of the wetland will be dominated by mangroves, while the more interior, freshwater parts will grow mixed forest and saw-grass. Erosion by storm impacts is widespread and recovery generally slow or absent.

Wetlands in particular are threatened by accelerating sea-level rise. Supratidal flooding causes salinity changes affecting the wetland vegetation and may adversely affect spawning fish stocks which grow in wetland areas. Most wetlands will shrink and eventually disappear unless the rate of sedimentation within the wetland can keep pace with sea-level rise.

Figure 4.30: Wetland Erosion in Southeast Jamaica Following Passage of Hurricane Dean (August 2007)

Coral reefs

Jamaican coral reefs, like most others in the Caribbean, have undergone drastic changes over the past 30 years from increases in hurricane activity (Goreau, 1959, Woodley, 1992) and biological catastrophes declined from 50 percent or more cover to 1-2 percent. The mortality principally resulted from (Hughes, 1994). Reef corals suffered catastrophic mortality in the 1980s, so that live coral abundance overgrowth of the corals by fleshy algae, which had previously been controlled by the abundant echinoid *Diadema*. After a disease virtually wiped out *Diadema* in 1983-84, fleshy algae proliferated, as other herbivores, particularly fish species, had already been decimated by overfishing (Jackson, 2001). Additional factors influencing the reduction in coral populations have been increasing frequency of coral disease and bleaching events, probably resulting from unusually high sea surface temperatures (Goreau et al. 1992; Hughes, 1994; Jackson, 2001). Along the north coast of Jamaica these events were exacerbated by the previous passage, close offshore, of Hurricane Allen in 1980, which caused considerable mechanical damage to the reef systems, particularly affecting species of *Acropora* (Woodley, 1992). Minor recovery of coral populations has taken place in some localities (D'Silva et al. in prep?).

It has also been suggested that the continued dominance of fleshy macroalgae may be influenced by increasing nutrient enrichment in coastal waters from run-off (Lapointe, 1997; see also Mutti & Hallock, 2003) but this remains a controversial topic. The effect of increased acidity on reef corals will probably be negative as calcification in many reef-building species will be reduced. The additional effect of increasing sea surface temperatures will lead to added stress on this biota with probable increased bleaching events, but the net results are difficult to predict. Reduced calcification may result in less robust skeletal structures, more easily damaged by storms (Guinotte & Fabry, 2008). Increased acidity will probably increase biomass and productivity for seagrasses (Guinotte & Fabry, 2008) so that sea-grass habitats may expand.

With rising sea-level, the increased stresses on the reef systems will probably lead to a reduction in the vertical growth rate as a whole so that the water will become deeper over the reef crest zone leading to a diminution of the protection it offers to future storm waves. This trend could be well advanced by 2050.

Saline Intrusion

Saline intrusion will increase with sea-level rise but the effects of such an increase are likely to be small. Saline intrusion is already a major factor in some parts of Jamaica due to over-pumping of groundwater wells. In the study localities used for this V&A assessment, water supplies were not drawn from wells sited near the coast, but from river systems. Water supplies are more likely to be affected by drought as populations increase into the future.

Anthropogenic factors

Although environmental stresses to coral reefs and other coastal ecosystems are both "natural" (i.e., not directly related to human activities) and anthropogenic in origin, human activities consistently amplify the impacts of naturally occurring stresses such as the passage of hurricanes and rising sea surface temperatures (Hallock et al. 2004). For example, the impact of a natural event such as a hurricane on coastal ecosystems is greatly and progressively amplified through time by deforestation, agriculture runoff, and coastal development leading to increased population pressures on the coastline.

The main anthropogenic stresses on the coastal zone, not directly related to climate change, arise from population increase and migration to the coastal zone, leading to:

- Informal settlements (squatting);
- Increased chemical pollution of coastal aquifers and the near-shore area from sewage and agricultural runoff;
- Increasing proliferation of hardened engineering structures along the coastline, leading to progressive beach erosion;
- Insufficient planning and siting of critical facilities, overburdened by population pressures; and
- Private ownership of coastal land which restricts public access to the coastline.

The long-term goals of Integrated Coastal Zone Management for conservation of coastal resources and sustainable development are often incompatible with the desire for a short-term economic gain by interests in the tourist and other industries.

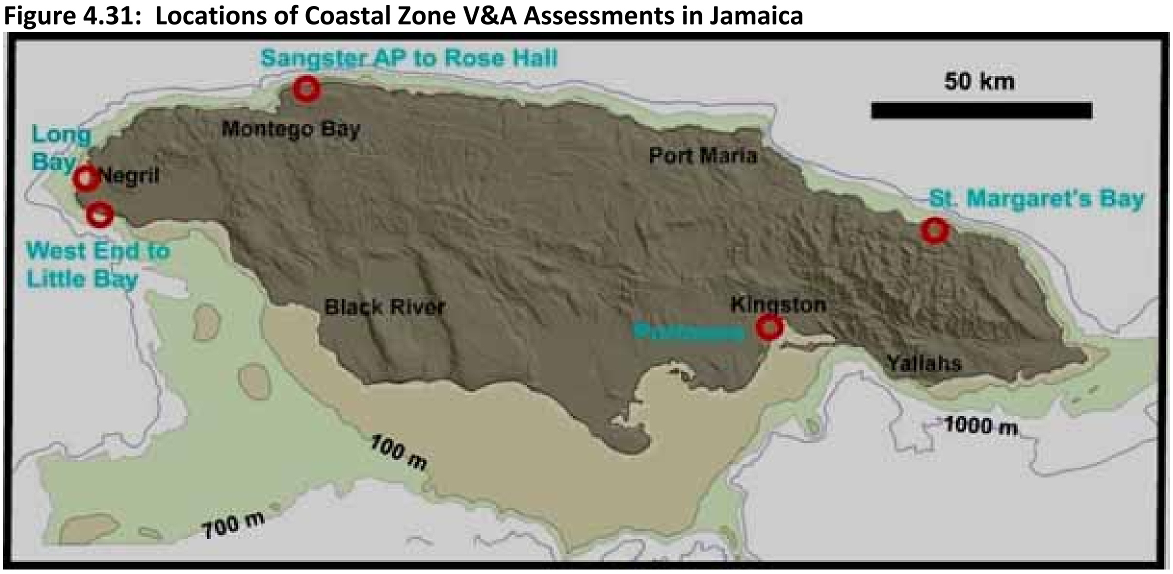
4.5.4 V&A Case Studies

Five areas were selected for case studies based on a variety of features which, collectively, characterize much of the Jamaican coastline. They are:

- St. Margaret's Bay, Portland
- Sangster Airport to Rose Hall, St. James.
- Long Bay, Negril, Hanover & Westmoreland
- West End to Little Bay, Westmoreland
- Portmore, St. Catherine

The locations are indicated on Figure 4.31.

Figure 4.31: Locations of Coastal Zone V&A Assessments in Jamaica



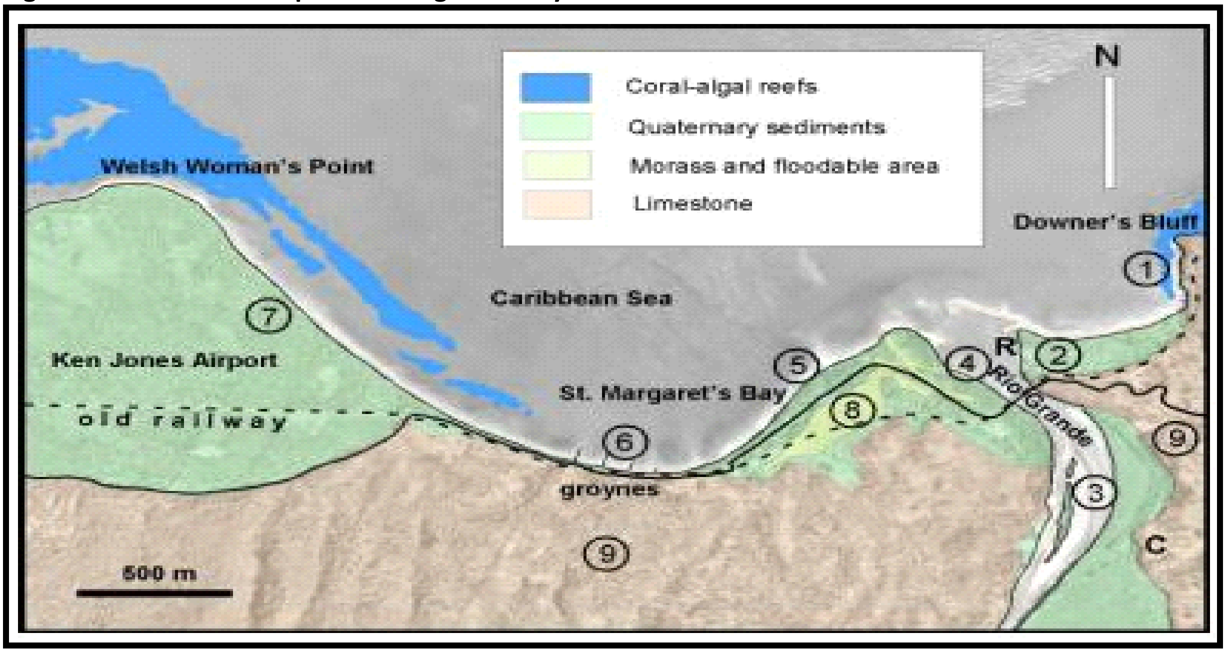
1. St Margaret's Bay, Portland

The settlement of St. Margaret's Bay is situated at the mouth of one of Jamaica's largest rivers, the Rio Grande. The river is the source of sediments for the beaches of the adjacent coastline and a cause of riverine flooding which, on many occasions, coincides with intense tropical storm activity. The Rio Grande experiences some of the most frequently recurring flood events in Jamaica.

Connections with the rest of Jamaica are limited, principally via the coast road, currently under improvement as part of the North Coast Highway project. A beach monitoring programme has been maintained there since the end of 2003 by the Marine Geology Unit.

The St. Margaret's Bay area has been undergoing periodic bouts of coastal erosion since Hurricane Allen in 1980. The erosion has placed beachfront residences in jeopardy, with at least one home having lost a room to the sea. The coastline has a tendency to retreat and prograde seasonally. The passage of storms has retarded the recovery of the beach after major erosive events. The community is also subject to flooding from the Rio Grande-fed swamp which lies behind the village. These flood events occur after heavy rains when water from the swamp floods homes and the main thoroughfare. During storms, floodwaters which usually find their escape to the beach are backed up by storm surge cutting the main coastal highway (currently under reconstruction).

Figure 4.32: Location Map of St. Margaret's Bay



Source: Reprinted from Robinson et al., 2003

The community of St. Margaret's Bay is situated along a low-lying, embayed coastline immediately west of the mouth of the Rio Grande in Portland Parish. Housing is strung out on both sides of the main north coast road (Robinson et al., 2003; Rowe et al., 2003). The area includes in a four-kilometre stretch of coastline extending from Downer's Bluff in the east to Welsh Woman's Point in the west. The area includes the estuary of the Rio Grande and a small wetland behind the coast road.

Immediately west of the estuary (numbered 5 on Figure 4.32), the beach fronting much of the settlement of St. Margaret's Bay is the most mobile in the bay, showing significant, alternating phases of erosion and accretion. During 2004 and early 2005, several profiles were established and monitored along this section of the coastline, and one of these continues to be monitored.

The wetland behind the eastern part of St. Margaret's Bay settlement (numbered 8 on Figure 4.32) becomes inundated during flood events in the Rio Grande Valley and from heavy rainfall events at the coast when water and debris floods occur in the coastal gullies. The flooding is exacerbated by the overgrown and blocked drainage designed to exit to the sea at the mouth of the Rio Grande The flooding frequently extends over the main coast road (now in course of reconstruction). When combined with stormy sea conditions many members of the community become isolated.

Over most of the year wave trains travel from the northeast, but during the winter months they frequently originate from the northwest, as a result of northers. A survey of the island shelf was carried out by the Marine Geology Unit early in 2004. The shelf is very narrow opposite the settlement, only 200 to 400 metres in width. The shelf edge breaks at about 12m depth. To seaward, the sea floor steepens sharply to depths in excess of 1000m. The top part of what may be a submarine canyon (Robinson et al., 2004) appears to be present just northeast of the mouth of the river. Bay sediments are dominated by mud.

Sediments forming the beaches of the St. Margaret's Bay area are derived from two sources. By far the most important is the sediment discharge of the Rio Grande. A minor secondary source comes from carbonate sediment production within the reef areas at the eastern and western extremities of the bay.

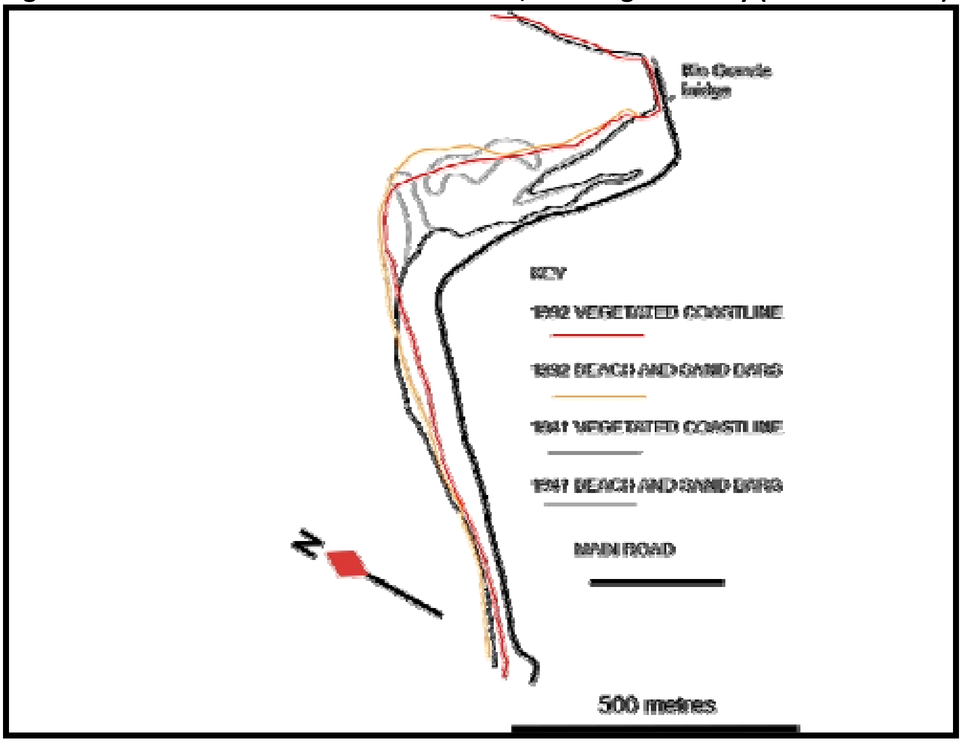
Vulnerability

The main hazards affecting the community of St. Margaret's Bay are from wave and surge activity caused by tropical cyclone systems and northers, and riverine flooding from the Rio Grande, and, to a lesser extent, from locally intense rainfall.

The section of St. Margaret's Bay immediately to the west of the mouth of the Rio Grande is particularly vulnerable to shoreline changes. While flood events in the river supply coarse sand and cobbles to the beach area, riverine flooding causes water levels to rise in the wetland and overflow the road, inundating property on both sides of the road. Most of the cobble beach between the river and the old groynes is susceptible to periodic erosion and recovery (erosion has dominated) from passing tropical storm systems and from winter northers. Net shoreline changes along this segment of the coast are derived from comparison of aerial photographs taken in 1941 and 1992 and are shown in **Error! Reference source not found.**.

Along the stretch of coast fronting the airport erosion losses have been small, but the passage of Hurricane Allen in 1980 caused inundation of the eastern end of the airport runway (Wilmot-Simpson, 1980). At the northern end, the dunes were also overridden by waves and surge from Hurricane Allen.

Figure 4.33: Variations in Shoreline Position, St. Margaret's Bay (1941 and 1992)



Socio-economic assessment

St. Margaret's Bay, with a population of 697 (STATIN, 2003), is a fishing community immediately west of the mouth of the Rio Grande in Portland Parish. Residential and small businesses (grocery, tailor, hairdressers, etc.), as well as a few larger commercial enterprises (woodwork, mechanic, block making, etc.), are strung out on both sides of the main road. Summerset Falls and Ken Jones aerodrome are the only two large entities in the area providing economic stability to the community.

The single road through the community is the only corridor on which residents depend for transport of goods and services and it is the only evacuation route to the single shelter located at the St. Margaret's BAY all-age school. The weakest point along this corridor is the bridge across the Rio Grande which in 2004 was damaged by flood waters related to Hurricane Ivan and impassable to vehicular traffic. The vulnerability of other sections of the road to flooding (Beaches, 2006) and erosion is evidenced by the remains of sections of the railway line which ran along the coast, north of the main road, and was damaged in 1980 from storm wave impact and erosion. The complete absence of railway lines along sections of the bay is an indicator that the main road is also at risk. This would have very serious consequences for residents as well as the nation as this is one of only two routes to the eastern part of the island.

The limited economic opportunities and repeated impact on the area by flooding and loss of land to coastal erosion (Beaches, 2006) is reflected in the decrease in population size by 65 percent over 1991-01 (PIOJ, personal communication). Although the construction of the north coast highway to Port Antonio promises improved transportation access, the downscaling of other operations – particularly air travel – will probably lead to continued economic decline in the community.

2. Sangster Airport to Rose Hall, St James

The northern St. James coastline from Sangster International Airport as far east as Rose Hall is a region with mature hotel and tourist industrial development and continuing new developments. The hotels and guest houses along the coast are backed by large planned and unplanned settlements, such as Ironshore and Barrett Town.

The physiography of this region consists of a narrow coastal plain, behind which the land rises steeply to summits of 250-300m about 3.5km south of the coastline. The back coast hills are drained by a number of steep gullies. The coastal plain along here forms a low-lying platform of variable height. A series of small pocket beaches is interspersed with the rocks of the limestone platform and outcrops of gravel from the gullies. The coast is protected offshore by a more or less continuous reef, sheltering a lagoon between the reef and the coast, although in many places the reef crest is close inshore. The reef is incompletely developed opposite Mahoe Bay. The lower courses of the larger gullies transit and are incised into a series of debris fans, which are evidently the result of former sediment deposition from the gullies. The gullies evidently carry storm water and debris from time to time as is evidenced by the modern debris fan deposits growing at some of the gully exits to the coast.

All along the north coast, the rocks forming the limestone terrace in the coastal plain are faulted and warped to varying degrees, indicative of seismic activity continuing to the present day (Horsfield, 1972). This terrace was formed only about 130,000 years ago, so that the region as a whole must be considered as still seismically active. Faulting affecting more recent unconsolidated or semi-consolidated sediments is difficult to identify, but the continued occurrence of earthquakes is well documented (e.g. Robinson et al., 1960). The most recent large local earthquake was that of March 1, 1957, with an epicentre located near Montego Bay (Robinson *et al.,* 1960). There is no evidence that any earthquakes have caused relative changes in sea-land levels.

Vulnerability

The coast is susceptible to significant storm surge (SWIL, 1999) and is also a coast vulnerable to tsunami with very short lead-time warning periods. Other hazards include the possibility of extreme rainfall events generating debris flows in the numerous steep gullies and rivers which descend to the coast. These have been recorded in the past (ODPEM catalogue).

The fringing/barrier reefs along the St. James coast are relatively close inshore in the central part of the coastline with accompanying narrow lagoons. As such, the availability of an adequate natural supply of carbonate sand may be compromised. With the rise of sea surface temperatures and increasing acidity of the oceans, and with likely significant increases in polluted runoff from the island, it is likely that the existing carbonate production rates will decline quite steeply. Beaches will probably require periodic nourishment, starting within the next couple of decades, to continue as part of the tourist package.

Socio-economic assessment

Sangster's International Airport is the leading tourism gateway to Jamaica. The airport is located on the northwest coast amid a wide range of hotel and resort facilities and other commercial entities. The airport runway is partially bounded to the north by a swamp know as North Ponds and lies south of Kent Avenue, the coast-parallel road.

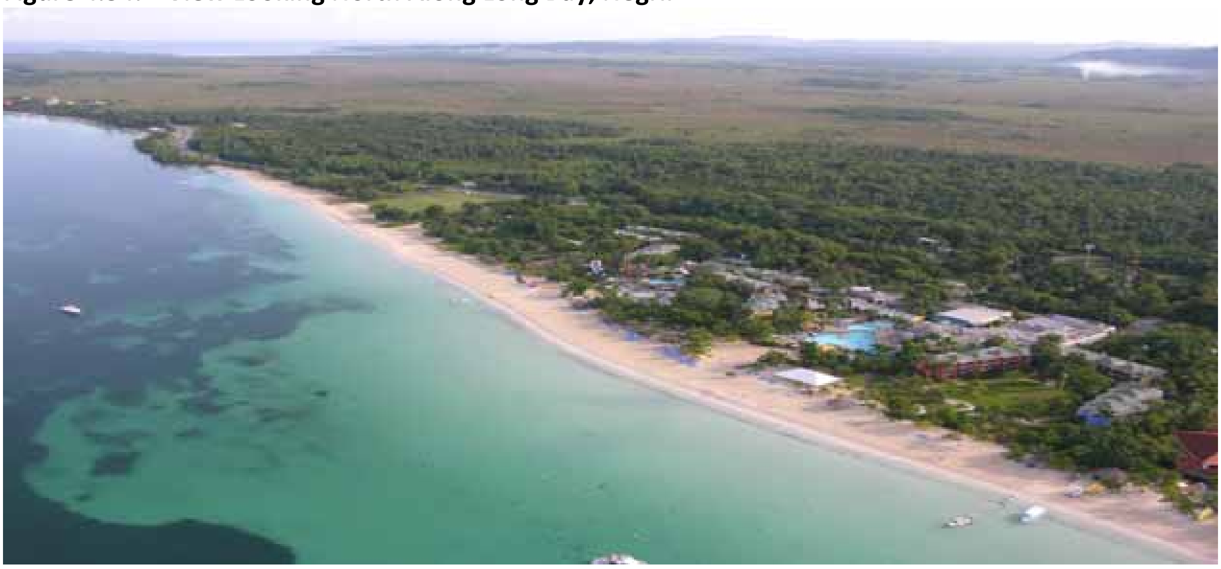
This western section of coastline is dominated by small commercial business including restaurants, bars, and groceries and a small fishing village. Much of the infrastructure in the area consists of wooden houses. Large hotels with capacities of over 250 persons increase in numbers towards the east and dominate much of the north coast between Sangster International Airport and Rose Hall. Many of these hotels report beach erosion episodes, coastline retreat, and storm surge inundation as reoccurring negative impacts due to hurricanes and storms. There is need for diversification of industry away from the focus on tourism, which is subject to external factors largely beyond the island's control. Light industry and agro-industrial activities could be encouraged for the medium and long term.

3. Long Bay, Negril, Hanover, and Westmoreland

The resort area of Long Bay, Negril, is confined to a narrow strip of low-lying land (mainly sand) between the sea and the wetland of Negril Morass, forming a barrier beach system over which elevations are 2m or less above sea-level (Marine Geology Unit, 2008). Long Bay straddles the boundary between the parishes of Hanover and Westmoreland. The morass is a low, more or less level wetland underlain by peat, up to 12m thick in places. The load-bearing capacity of peat deposits for construction purposes is essentially zero, thus limiting building expansion into the morass area and restricting further development to the coastal strip.

The barrier beach system at Long Bay is a relatively narrow complex, consisting of unconsolidated to poorly consolidated carbonate sand overlying either limestone bedrock or peat deposits at depth (Hendry, 1982; Mitchell et al., 2002). Recent measurements of elevations over the barrier indicate that heights above sea-level range from approximately 2m in the northern part to about 1.5m or less towards the southern end (MGU, 2008). The active beach is more or less continuous from end to end of the bay, except for a point in the middle of the UDC Beach Park, where rocky outcrops are exposed in the foreshore.

Figure 4.34: View Looking North Along Long Bay, Negril



White sand beach with hotel buildings behind, on the 1.5m high barrier system. Great Morass is behind the trees. Image courtesy of N. Butterfield.

The morass behind the barrier beach system is a mainly freshwater wetland, dominated by sawgrass (*Cladium*). Elevations over the morass do not exceed 2-3m near its eastern margin, and most of the region is at or near sea level. It is underlain for the most part by peat of varying thickness, up to 12m in places near the beach system (Robinson, 1983, appendix 1). The morass formed as a wetland about 8,000 years ago in a marine to brackish environment as the post-glacial sea-level rise flooded the region, with an extensive mangrove (*Rhizophora*) flora. It became increasingly fresh water through time as the barrier beach developed in front of it and springs at the foot of the limestone hills to the east became the main source of water (Digerfeldt & Hendry, 1987). Until the 1950s, drainage was via the South Negril River and the now largely defunct Middle River which exited into the middle of Long Bay.

In the late 1950s, a canal was constructed along the east and north side of the morass as part of a drainage scheme to improve the agricultural potential of the area. This cut off the supply of fresh water to the wetland, reducing the flow of the Middle River, lowering the water table, and leading to an increased growth of forest and bush, fed by rainfall. Increased human encroachment into the morass since the 1950s has included cutting of forest vegetation, particularly the stands of royal palms at the southern end of the wetland, and widespread cultivation of market garden crops and marijuana (*Cannabis*) along the eastern margin (Bjork, 1983). The drainage and agricultural practices have led to subsidence of parts of the wetland, grossly reducing the effectiveness of the main canal as a drain. Within the canal, tidal effects and saline encroachment have led to the development of mangrove stands along the northern extension of the canal.

Vulnerability

The principal natural hazard is from surges generated by severe weather conditions, but beach changes are an ongoing feature for several parts of Long Bay. Erosion tends to be greatest during the winter months when the bay is vulnerable to wave trains coming from the northwest and west as a result of northers (e.g. SWIL, 2007). The low elevations along the barrier system will lead to extensive marine inundation and erosion over time (MGU, 2008). For example, in the “hot spot” identified at Conch Hill and the northern boundary of Swept Away**Error! Reference source not found.**, and using 2003 as the starting point, preliminary calculations suggest cumulative shoreline retreat to average 4-7m by 2008 (this year), 10-15m by 2015, 26-41m by 2030, and 51-94m by 2050. Estimates using the Bruun Rule give somewhat lower values. Actual values measured by us for this period averaged about 3 m.

Socio-economic assessment

At the present day, the entire effort at Negril is devoted to local and foreign tourists and holiday rentals. As for St. James, diversification beyond the focus on tourism is needed, particularly in the direction of ecotourism, using parts of the wetland and mountains to the south and east. It should be recalled that Negril morass contains thick peat deposits extensive enough to be used *in extremis* for electric power generation (Robinson, 1983).

4. <u>West End to Little Bay, Westmoreland</u>

This coastline is characterized by low coastal cliffs and is currently experiencing development at an accelerated rate. Communities and buildings suffered considerable damage from the passage of Hurricane Ivan in 2004, from Emily and Wilma in 2005, and from Dean in 2007 (Figure 4.35). Much of the damage resulted from large blocks and boulders being torn from the cliff face and hurled ashore

(Robinson et al., 2006). Sea level rise will lower the cliff top relative to sea level, and enhance the ability of extreme wave events to damage the cliff top communities.

Figure 4.35: Boulders at Brighton, near Little Bay, Strewn Over Access Pathways as Result of Passage of Hurricane Ivan (2004)

The coastline of this part of Jamaica is unusually straight, with a straight, narrow island shelf, strongly suggesting it is associated with a shore-parallel fault system. This probability is reinforced by the fact that the rocks exposed at the coastline are extensively fractured. Although one or two small pocket beaches have developed, for the most part, the coast consists of a low jagged cliff without beaches, forming the front edge of a coastal platform consisting of Upper Pleistocene (c. 130,000 year-old) reef and shelf limestone, varying in elevation between about 1m and 4m above sea-level at the shore, to about 10m at the rear of the platform. The area is backed by a steep escarpment, the remains of an old sea-cliff (Cant, 1973). There is no surface drainage.

Vulnerability

The debris along the shoreline has been emplaced by giant wave impacts; the ridges have most likely resulted from the progressive emplacement and movement, throughout the past four or five millennia, of storm and/ or tsunami generated debris over the platform into zones where the energy level of the impacting waves or surge is reduced. Clasts accumulate, evolving into ridges that increasingly provide a barrier to the further incursion of debris inland. Incursion is probably further inhibited by the increased roughness of the terrain, provided by the forest cover, still present in undeveloped sections of the coast. The large isolated boulders are torn off from the platform bedrock and are either in-transit towards the ridge deposits, or following initial emplacement on the platform, are too big to be moved subsequently by hurricane-generated waves. In the latter case, initial emplacement may be from tsunamis. The perched beach deposits are essentially ephemeral, formed during the passage of storms, and modified or destroyed by later wave events (Robinson et al., 2008).

The fractured nature of the rocks forming the coastal cliff makes this coastline particularly susceptible to erosion by destructive storm waves and surges. During a storm event, such as the recent passages of hurricanes Ivan (2004) and Dean (2007), boulders up to several tens of tonnes mass are broken off the cliff face and carried across the platform for varying distances with potential for damaging buildings, while boulders already on the platform may be carried further inland. Other boulders get broken off and dropped into the sea at the foot of the cliff, or may be sucked out to sea by the backwash of the waves, perhaps to be brought ashore subsequently during a later storm.

For coastal management practices, the position of the debris ridge is thus critical, effectively delimiting that seaward part of the platform, vulnerable to storm impacts, from the protected area behind the ridge. Destruction of the ridge and clearing of the forest during development projects increases vulnerability to storm impacts of those areas originally protected by the ridge.

Figure 4.36: **Southwest Coast, East of Negril Lighthouse** (upper left), showing fractured rocky platform zone without vegetation that is frequently swept by storm waves. Crowded boulders visible at right mark the front of the debris ridge, extending behind the green house

Socio-economic assessment

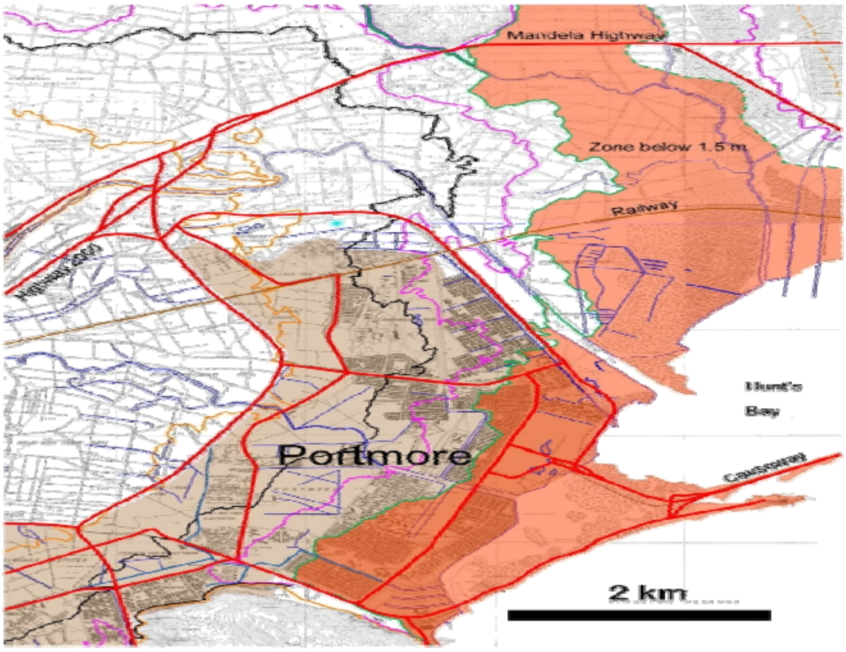
This coastline is currently experiencing development at an accelerated rate, with significant hotel development concentrated towards the west. The Little Bay end of the coast is relatively isolated and still retains a small community largely involved in fishing and agriculture. Although isolated, it is an attractive coastline and some holiday homes and small hotels have been built. There is no direct access to the Little Bay end from West End. The most direct route connects with the highway between Negril and Little London. It is likely that tourist/ local vacation homes will expand along here.

Communities and buildings suffered considerable damage, including destruction of some 15 houses, from the passage of hurricanes in 2004, 2005, and 2007. The placing of future buildings along this coast should be guided by the position of the debris ridge, which provides protection from storms.

5. Portmore, St. Catherine

Portmore is a coastal city with a population of over 90,000 (as of 2001) and with land elevations mostly below 10m. Figure 4.37 shows the general topographic features. Contour lines are at 1.5 m (green); 3m (pink); 4.6m (black); and 7.6m (orange). Areas below 1.5m are shaded red; built-up areas are shaded brown. Greater Portmore is situated on low-lying land adjacent to the west side of Kingston Harbour and surrounding Port Henderson Hill, which rises abruptly from the plain (Figure 4.37). The hill consists of white limestone overlying metamorphic rocks, seen in tiny exposures on the northwest side of Green Bay. On the north side of the hill, marl and sandy limestone belonging to the August Town Formation (Miocene-Pliocene age) are steeply inclined to the northeast (Coates, 1970).

Figure 4.37: Topography of Portmore and Approaches



Greater Portmore itself lies on sand and gravel sediments belonging to the more distal part of the alluvial fan of the Rio Cobre. A seismic traverse carried out south from Spanish Town indicated thicknesses of the formation up to about 200m (Makowiecki, 1964). The alluvial fan extends as far west as Portland Bight. The Rio Cobre evidently flowed into Galleon Harbour at some time in the distant past.

Closer to the shore of the harbour, the sediments consist of recent deposits of sand, peat and mud, and areas that originally were salt flats. Before the latter part of the 20th century, the spit ending at Fort Augusta was separated from the mangrove mud and lagoon area to the west of the spit. Much of this area was filled in during the construction of the city of Portmore and its road connections. Old courses of the Rio Cobre are evident on aerial photographs, before it was confined to its present canalized course into Hunts Bay.

Vulnerability

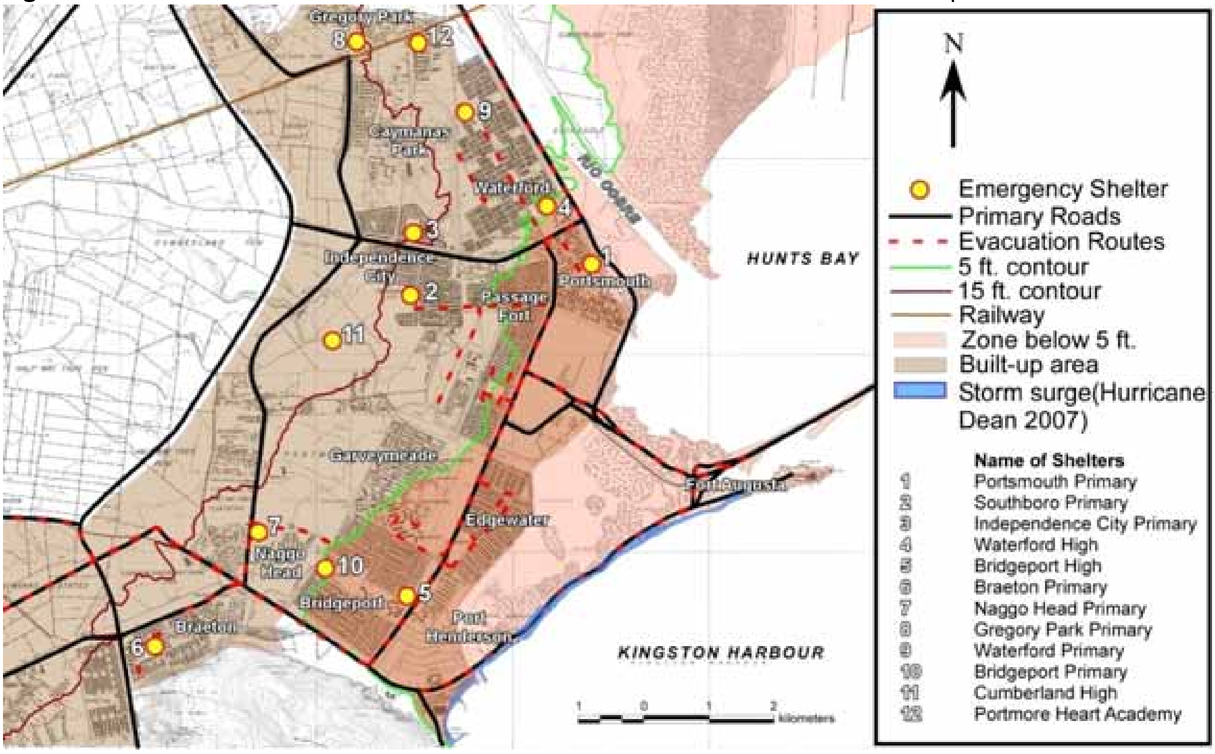
Figure 4.37 indicates those areas that are less than 1.5m above datum. The region below 4.6m in Figure 4.37 is at the height of the highest storm surge reported historically for Passage Fort (now part of Portmore; ODPEM historical notes); while the area below 7.6 m is the zone used in this report to focus on places that might be vulnerable to coastal hazards. The historical quote follows:

> *On September 8-9, 1722, Jamaica was hit by a hurricane, which brought with it heavy storm surges. Port Royal and Queenstown (now Passage Fort) were destroyed by a surge of 16 feet. A surge also occurred in Kingston Harbour*.

A 2008 investigation of the vulnerability to storm surge was carried out through CDERA with funds from the Inter-American Development Bank (SWIL, 2008); however the final reports had not been released at the time of this assessment. The 2008 Smith Warner report succeeds an earlier one on the planned extension through Portmore of Highway 2000 (Smith Warner, 2000). Another vulnerability report being prepared by the Mines and Geology Division and the Office of Disaster Preparedness and Emergency Management is also in the review stage, funded by the UNDP (2008). There is need to evaluate these results in conjunction with simultaneous flooding from the Rio Cobre and local intense rainfall, and in comparison with historical records of storm surge activity in the Kingston Metropolitan Area.

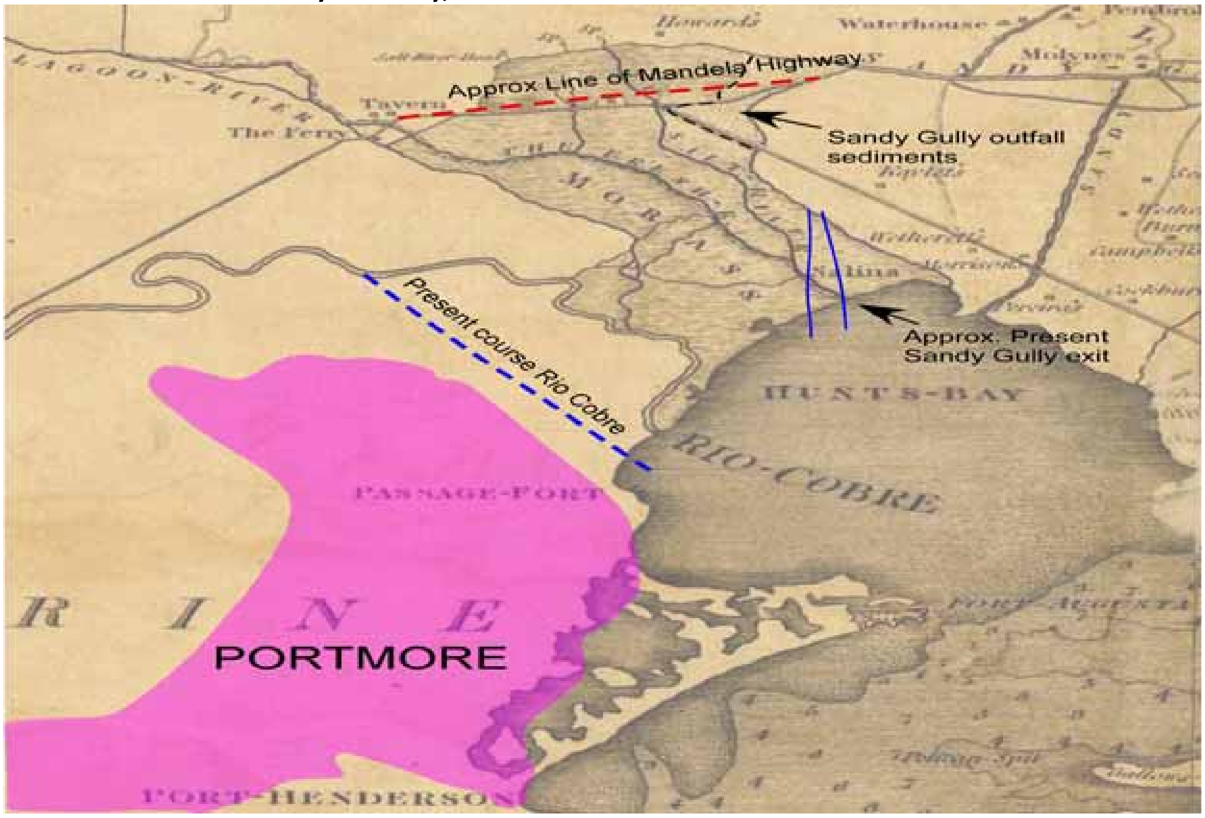
Although the municipal area of Portmore is not likely to be susceptible to subsidence – except, perhaps along the extreme coastline area – the same cannot be said for some of the evacuation routes. There is a strong possibility that the wetland north of Portmore and extending across the Mandela Highway is subsiding due to peaty sediment compaction and sediment starvation resulting from the diversion of Sandy Gully into Hunts Bay and training of the Rio Cobre, although no studies have been undertaken.

Figure 4.38: Portmore Evacuation Routes and Shelters. Area below 1.5m shaded pink.



The Robertson map of 1804 shows an area of wetland (morass) extending from the north side of the then course of the Rio Cobre as far north as the limestone foothills northwest of Kingston (Figure 4.39). Kingston's Sandy Gully system used to drain into the eastern part of this wetland. As the 1804 map indicates, this region lies between now inactive sections of the alluvial fans of the Liguanea Plain to the east and the Rio Cobre to the west. The continued sediment infill between the two fans was at that time driven by the run-off from the degrading of the Liguanea fan, bringing relatively coarse sediments to the region, deposition of relatively coarse sediments from the Rio Cobre, and muddy sediments being deposited by the Fresh and Duhaney Rivers (Robertson, 1804) accompanied by extensive development of mangrove and other wetland vegetation.

Figure 4.39: Map of the Passage Fort and Hunt's Bay area, part of Robertson MAP of the County of Surrey, 1804



Source: Robertston, 1804. Reproduced with permission of the National Library

The Sandy Gully and Rio Cobre sediment supplies have now been diverted into Hunt's Bay, thus depriving the region of sediments that would assist in reducing subsidence. Borings made in the 19th and 20th centuries in connection with the railway, and more recent borings drilled for the extension of the port of Kingston, indicate significant layers of peat and mud surrounding Hunt's Bay. The whole region between the two alluvial fans has been in-filled in geologically recent times and the sediments there are likely to be unconsolidated and with high interstitial water contents. Compaction, with accompanying on-going subsidence is thus very likely.

Socio-economic assessment

The city of Portmore, population 156,469 (STATIN, 2003), is located on low lying marsh lands and is bounded to the east by two water bodies the Kingston Harbour and Hunts Bay. The community of Port Henderson is located along this eastern coastline and is the location of Jamaica's only female penal institution, Fort Augusta. Several small individually operated businesses, primarily restaurants, bars, amusement venues and small hotels, are strung along both sides of the main road. A small informal fishing community has developed along the coast consisting of primarily of wooden structures. Many of these were destroyed by storm surge generated by Hurricane Dean in 2007.

The single road through the Port Henderson community is the only corridor on which residents depend for transport of goods and services and serves as the only evacuation route for the 839 persons (PIOJ-personal communication) who reside in the area. The elevation, less than 5ft above sea level, and position of the road, bound to the east by Kingston Harbour and to the west by low-lying swamps, exposes it to repeated inundated and during hurricane events and has been blocked by debris and sand deposits making it impassable. Partial and/or complete destruction of buildings along this section of the coastline during storm events highlights the continuous threat that storm surge poses to this community.

The quality of water supply is another problem that faces the community of Portmore (pers. comm., WRA 2008).

4. 5.5 Development of a Coastal Zone Vulnerability Index

Vulnerability may be defined as the degree of loss or damage that would result from the occurrence of a natural phenomenon of given severity. In assessing vulnerability for the purposes of long term development and adaptation to sea-level rise, it is appropriate to apply an index of vulnerability to every segment of the coastline, based on a standardized set of criteria. These criteria may be physical, or socio-economic, or both. The approach documented here attempts to combine a coastline's susceptibility to sea-level change with its natural ability to adapt to changing conditions. This yields a quantitative result that can be applied in a relative sense as a measure of a coastline's natural vulnerability to sea-level rise effects (Gutierrez et al., 2007). While this approach allows decision makers to identify those sectors of the coastline at higher risk, it is not a predictive tool for coastline change.

Defining an Index of Vulnerability

The parameters for constructing the Coastal Vulnerability Index (CVI) used in this report are the same as those used by the US Geological Survey (USGS) for the nation and its territories (Table 4.32):

1. Geomorphology and geology;
2. Historical shoreline change rate;
3. Regional coastal slope;
4. Relative sea-level change rate;
5. Mean significant wave height;
6. Mean tidal range.

Table 4.32: Parameters Used for Calculating the Coastal Vulnerability Indices

	VULNERABILITY				
VARIABLES	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
	1	2	3	4	5
Geomorphology, geology	rocky cliffed coasts	medium cliffs	low cliffs, alluvial plains	beaches, lagoons	sand beaches, wetlands, coral reefs
shore erosion/ accretion (m/yr)	> 2.0	1.0 to 2.0	1.0 to 1.0	-1.0 to 1.0'	< -2.0
coastal slope (%)	> 14.70	14.69 to 10.90	10.89 to 7.75	7.74 to 4.60	< 4.59
sea-level change (mm/yr)	< 1.8	1.8 to 2.5	2.5 to 3.0	3.0 to 3.4	> 3.4
mean wave height (m)	< 1.1	1.1 to 2.0	2.01 to 2.25	2.26 to 2.6	> 2.6
mean tide range (m)	> 6.0	4.0 to 6.0	2.0 to 4.0	1.0 to 2.0	< 1.0

Source: Modified from Pendleton et al., 2004

The ranking of data also follows that used by the USGS (e.g. Pendleton et al., 2004). Each variable is assigned a vulnerability ranking on a scale of 1 to 5 based on the actual numerical value (parameters 2 to 6) or qualitatively, as a measure of erodibility, for geomorphology and geology (parameter 1), based on an assessment of the coastal morphology, beaches or lack thereof, resistance of rocks to erosion, etc. Derivation of information for each parameter is modified from that used by the USGS and is as follows.

- *Geomorphology and geology.* Data for geomorphology were obtained from the standard geological maps for each region, together with aerial photographic analysis and field visits.

- *Historical shoreline change rate:* Shoreline erosion/accretion rates were calculated from a comparison of the IKONOS images (2003) with historical aerial photographs for each region. The rates of erosion/accretion were derived from changes between the digitized shorelines at each of the case study locations, along transects 1km apart or less, as indicated, and averaged for each locality. Because of the wide spacing of transects, the resulting data must be regarded as giving a very preliminary indication of relative vulnerability. A more detailed report on erosion potential at Long Bay is given by the Marine Geology Unit (2008).

- *Regional coastal slope.* Due to the lack of adequate off-shore and on-shore elevation data for many areas, the regional coastal slope was obtained by measuring the distance from the edge of the island shelf to the 7.6m (25ft) contour line on the topographic maps along the same transects used for the shoreline change measurements. The elevation difference at the ends of each transect divided by the distance gave the average slope value.

- *Relative sea-level change rate.* The value for relative sea-level change rate had to be estimated from regional data as Jamaican tide gauges have operated only intermittently. Therefore, an island-wide value was applied for the present day and future scenarios, derived from IPCC projections as contained in Table 4.29. This variable (about 3mm/yr in 2008 will be the same for each location but will have an increasingly important weighting into the future.

- *Mean significant wave height.* Estimates of mean significant wave height were obtained from a variety of sources; including expert opinion and records of moored buoys south and west of Jamaica maintained by the National Data Buoy Centre and must be regarded as provisional. For future projections, the mean significant wave height was taken to be similar to that at the present day.

- *Mean tidal range.* The mean tidal range was taken as being the same for all locations studied although local variation probably exists. There is insufficient data presently available to indicate whether or not the present range will change in the future.

Coastal Vulnerability Index Results

The resulting Coastal Vulnerability Index (CVI) was derived for each coastal segment studied by taking the square root of the product of the assigned variability value for each parameter and dividing the result by the number of parameters. The number of observations is too few for statistical analysis but the study areas have been ranked according to the mean values obtained for each location. It is emphasized that the ranking is based on relative vulnerability to long term sea-level rise, not to vulnerability from tropical storm and hurricane events. Notes on the derivation and definition of parameters used follow.

- *St. Margaret's Bay.* Slope values were obtained for five transects, spaced approximately 1km apart. Distances from the 7.6m contour to the shelf edge were based on bathymetry carried out by the Marine Geology Unit.

- *St. James coast.* Slope values were obtained for 16 transects, 1km apart. The shelf edge was assumed to be approximately 20m deep based on observation of photo images of the reef systems along the coastline and correlation with bathymetry available for Montego Bay. The position of the shelf edge was taken as the line marking the deep fore-reef sand talus deposits, obtained from aerial photograph inspection.

- *Long Bay, Negril.* Slope values were obtained for six transects taken 1km apart. Distances to the shelf edge were based on bathymetry from Digerfeldt & Hendry, 1987, and SWIL, 2007. The values obtained were the lowest for any of the sites examined due to the wide expanse of the Great Morass behind the Long Bay barrier beach system.

- *West End to Little Bay.* Ten transects along the low cliffs typifying this coastline yielded slope values based on unpublished bathymetry carried out by the Marine Geology Unit and associates in September 2007. Because of the rocky nature of the coastline, annual erosion rates were regarded as negligible, although rock falls and onshore boulder deposition from the cliff face during extreme wave events are common (Rowe et al. 2009 ~~in press~~, Robinson et al. 2006).

- *Portmore.* A Vulnerability Index for Portmore was not determined, but the physical parameters are similar to those of Negril, so that a comparably high index of vulnerability would be assigned to this location.

Table 4.33 summarises the results for each transect and the relative ranking in terms of vulnerability for four localities. Note that the higher the number, the more vulnerable is the locality to the effects of sea-level rise. For the localities examined, Negril rates as highly vulnerable, St. James and St. Margaret's Bay are moderately vulnerable, and West End to Homer's Cove is of low vulnerability to sea-level rise. The transect maps and detailed calculations can be found in Appendix 4.1.

Table 4.33: Coastal Vulnerability Indices for Sea-Level Rise. Column 7 at far right shows relative ranking of four study locations against their respective Coastal Vulnerability Indices in column 6.

Transect	West End	St Margaret's Bay	Negril	St James	Relative	Ranking
1	5.000	7.500	7.906	7.071	8	Negril
2	6.124	7.500	7.906	7.071	7.8	
3	6.124	6.708	7.906	7.071	7.6	
4	4.472	5.477	7.906	7.906	7.4	
5	6.124	6.325	7.906	7.906	7.2	
6	5.000		7.906	7.071	7	St James
7	5.000			6.124	6.8	St. Margaret's Bay
8	5.000			5.477	6.6	
9	5.000			6.325	6.4	
10	4.472			7.071	6.2	
11				7.071	6	
12				6.124	5.8	
13				7.071	5.6	
14				7.906	5.4	West End
15				6.124	5.2	
16				6.325	5	
MEANS	**5.25**	**6.81**	**7.91**	**6.88**		

Vulnerability to Tropical Cyclones

The probability of storms producing coastal flooding has been modelled for a number of localities in Jamaica, principally through environmental impact analyses carried out for hotel and other tourist-oriented developments. Estimates of the effects that sea-level rise might have on return periods for existing structures and elevations are suggested for Sangster International Airport, St. James, and Portmore, St. Catherine, based on Smith Warner International Ltd modelling of surge return periods for those localities (SWIL, 1999, 2000). For these projections, it is assumed that the temporal and geographical distribution and number and intensities of future hurricanes will remain the same as at the present day.

Also the water elevations associated with the respective return periods represent the static surge water levels, and do not include wave run-up. Addition of wave run-up would likely add 0.5-1.5m to the total effect of the storm water on the coastline, depending on the slope of the shore region and intensity of the storm. For Sangster International Airport, the most likely elevation of surge was used (SWIL, 1999, table 5). For Portmore, the values used in SWIL (2000, table 2.4) were used, less the value added for sea-level rise (0.07m). Approximate future return periods for Sangster International Airport and Portmore are shown in Table 4.34. The graphics for the return period calculations are in Appendix 4.2.

Table 4.34: Approximate Future Return Periods for Storm Surge Static Water Levels that Would Flood Current Elevations Above Sea-Level at Sangster International Airport and Portmore

Approximate return periods (years) for flooding the current elevation (IPCC, 2007)							
Location	**Current Elevations**	**SWIL, 1999**	**2015**	**2030**	**2050**	**0.6m**	**1.0m**
Sangster International Airport	0.5	3.5 - 4	3.5	about 3	about 2	100%	100%
	1	7	about 7	about 6	about 5.5	about 2.5	100%
	1.5	15	14	12.5	11.5	6.5	3.5
	2	100	94	81	56	12	7
	Current Elevations	**SWIL, 2000**	**2015**	**2030**	**2050**	**0.6m**	**1.0m**
Portmore	0.5	5.5	4.5	4	3.5	100%	100%
	1	10	9.5	8.5	7.5	4	100%
	1.5	14	13.5	13	12.5	9	5
	2	19	18.5	18	17	13	9
Approximate return periods (years) for flooding the current elevation (Rahmstorf, 2007)							
Location	**Current Elevations**	**SWIL, 1999**	**2015**	**2030**	**2050**		
Sangster International Airport	0.5	3.5 - 4	3.5	3	1.5		
	1	7	6.5	6	5		
	1.5	15.5	14	11.5	9		
	2	100	92	67	33		
	Current Elevations	**SWIL, 2000**	**2015**	**2030**	**2050**		
Portmore	0.5	5.5	4.5	3.5	2		
	1	10	9.5	8.5	6.5		
	1.5	14.5	13.5	13	11		
	2	19	18.5	17.5	15.5		

Data based on empirical examination of modelled return periods by Smith Warner International Ltd. for most likely static water elevations at Sangster International Airport (SWIL, 1999) and Portmore (SWIL, 2000). Wave run-up not included.

Additional water level elevations in Hunt's Bay resulting from extreme rainfall events were not included, but are indicated in Table 4.35.

Table 4.35: Possible Water Level Rise Due To Extreme Rainfall Events, Hunt's Bay

	Return Periods (years)				
Storm water runoff (m)	25		50		100
Static water level components	0.654 m		0.845 m		1.195 m

Source: modified from SWIL 2000, table 2.10

In the unlikely situation in which a 100-year hurricane surge coincides with a 100-year rainfall event, water levels in Hunt's Bay could rise by as much as 3.1m under present day conditions, not including a wave run-up component.

4.5. 6 Adaptation Measures

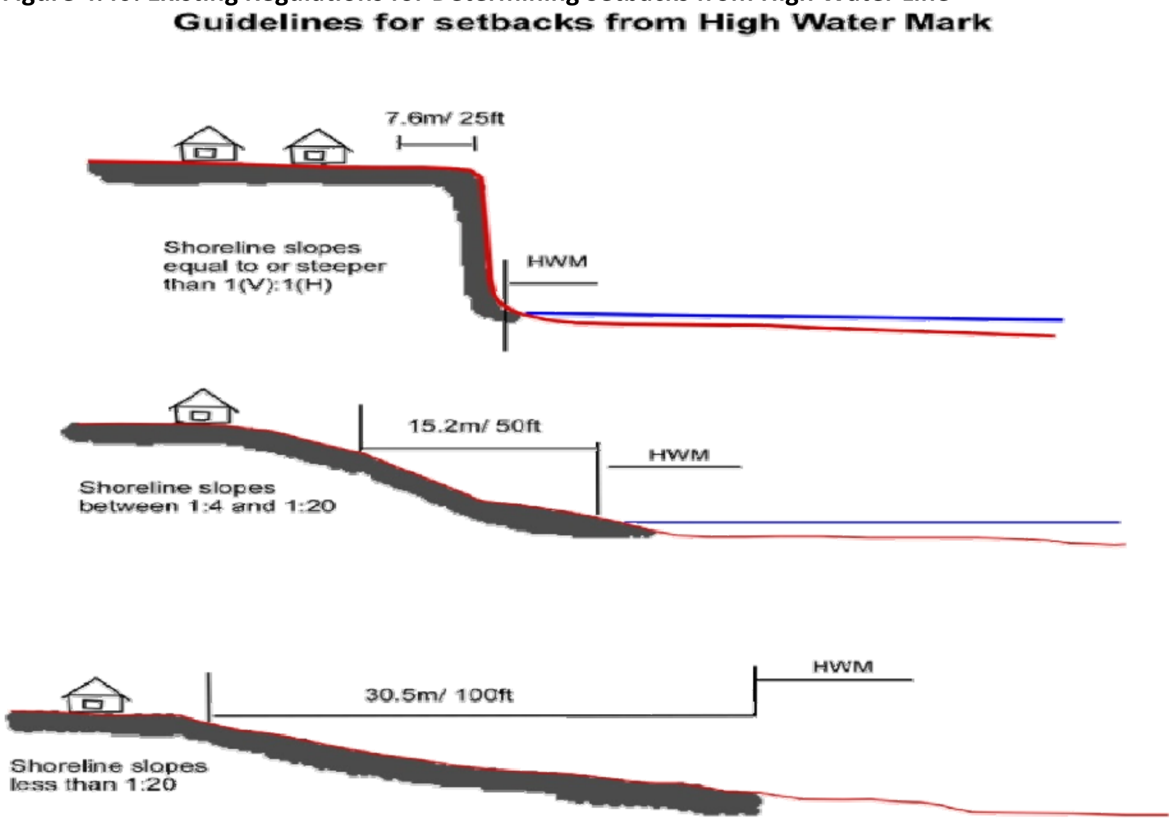
Adaptive measures for coastal zone management are normally classified into three categories (IPCC): retreat, accommodate, protect. Using a major, low-lying coast highway as an example, the options in the face of rising sea-level are: (1) to relocate the highway on higher ground away from the ocean, (2) to raise the roadbed above the expected elevation of future sea-level rise to accommodate the rise, (3) build a sea-wall to protect the highway at its existing elevation.

<u>Setbacks</u>

The currently available guidelines on setbacks (Town and Country Planning Authority) specify three categories of setback distance, based on shoreline slope categories referenced to the high water line:

- For slopes equal to or steeper than 1:1 (45 degrees), a setback of 7.6m (25 ft) is required;
- For slopes between 1:4 and 1:20, the required setback is 15.2m (50 ft), implying, at 1:4, a backshore elevation of 3.8m (12.5 ft); and at 1:20, a backshore elevation of 0.76m (2.5 ft);
- For slopes less than 1:20, the required setback is 30.5m (100 ft), implying a backshore elevation of 1.5m (at 1:20) or less.

Figure 4.40: Existing Regulations for Determining Setbacks from High Water Line



Source: Town Planning Department

As discussed by Smith Warner International (in SWIL, 1999), the three categories are not linked to any scheme of risk from inundation, as well as being internally inconsistent (change in setback at 1:20 slope, and no apparent guidelines for slopes between 1:1 and 1:4). There is need for revision of the guidelines so that equal risk is assumed, irrespective of shoreline type, for present day events. Ideally the guidelines should be more site-specific based on the local characteristics of the coastline, elevation, slope and erodibility, and estimated return periods of surges of a given elevation along the coast of interest.

For management purposes at St. Margaret's Bay, besides having an all weather coast road in place, further building along the strip between the beach and morass should be discouraged.

Structures on rocky coasts

As noted earlier, destruction of the debris ridge along the West End to Little Bay coast and clearing of the forest during development projects increases vulnerability to storm impacts of those areas originally protected by the ridge. Rising sea-level will reduce the relative height of the low cliff above sea-level thus allowing increased incursion of storm waves. Where the debris ridge is well-developed this will probably continue to offer protection to buildings, but where it is poorly developed or destroyed for construction material, increased vulnerability to storm incursion is likely (Figure 4.41).

Figure 4.41: A Hotel Built on Top of Debris Ridge, Southwest Coast Of Jamaica.
Permanent structures in front of the ridge should be discouraged.

All-weather roads

There is need to re-engineer sections of several major highways that serve coastal areas in Jamaica. There is limited entry to and exit from the Greater Portmore area, considering the size of the population. Evacuation in the event of an extreme weather event is via three main access roads that include low-lying and floodable stretches, especially the northern route into Kingston via the Mandela Highway. As at 2008, prolonged heavy rains flood both the highway and some of the approach roads leading into Portmore. In particular the highway is frequently flooded along the stretch that is below 1.5m above sea-level.

Draining the wetland adjacent to the Mandela Highway is unlikely to bring relief. The more likely result will be accelerated compaction due to the muddy and peaty nature of the substrate. With sea-level rise and possible continued subsidence there is urgent need to re-engineer the highway by raising the level of the road bed to convert what is perhaps the most heavily used arterial highway in Jamaica into an all-weather road. The other main route out of Portmore into Kingston crosses the Hunts Bay Bridge into an area of downtown Kingston that is also very low-lying and itself subject to frequent flooding.

Although the major Mandela Highway between Kingston and Spanish Town and cities further west is highlighted, there are other areas where the road bed needs to be elevated at least to 2-3m above sea-level to avoid increasing incidence of periodic flooding in the future. One obvious candidate is the highway along Palisadoes serving the Norman Manley International Airport. Long-term planning should incorporate this policy for all primary roads that service and provide access to with coastal communities, especially where emergency evacuation may be necessary.

Early warning systems in emergency management

Inhabited structures near the coastline, particularly the north coast (such as hotels) should be required to have emergency procedures in place for tsunami, and other possible sudden events (such as explosions or accidents releasing noxious gases, flash floods, and beach contamination with oil). As noted earlier, the seismic events generating tsunami are not thought to be related to climate change, but a rising sea-level will make built structures increasingly vulnerable to sudden flooding events. Warning systems for tsunami must be based on the expected short lead times between a seismic event and the arrival of tsunami waves and should include audible alarms such as sirens.

Beach nourishment

With the likelihood that natural sand supplies to carbonate beaches will be severely curtailed before 2050, there is need to identify suitable sources of sand for beach nourishment if the tourist industry plans to continue basing advertising on the coastal environment. The cost of nourishment is high and is an ongoing process, requiring repeat nourishment at intervals. Thus offshore sand reserves near to the tourist and public beaches should be a priority target. The Marine Geology Unit has identified extensive deposits (possible dunes) of carbonate sand on the South Coast shelf (Robinson et al., 2004).These are far from the potential clients but would be suitable for beach nourishment and extraction would probably not involve undue disturbance of the natural environment.

4.5.6 Constraints and Gaps

Coastal Vulnerability

A scheme embodying the principles used in constructing the Coastal Vulnerability Indices should be extended to the whole island. This can be done relatively quickly and at relatively low cost. An island-wide application of a Coastal Vulnerability Index would provide planners with a technical baseline for considering the merits of the various development schemes that will surely be suggested in the future. Preliminary research to perfect the most appropriate parameters would be a first step. Additional, non-physical parameters should be added as, for example, in the comprehensive scheme published by Meur-Ferec et al. (2008)

Setbacks

In addition to revising setback guidelines to accommodate a risk-based approach, research is needed into how the guidelines may be designed to accommodate sea-level changes through time because progressive sea-level rise risks are likely to change. Setback guidelines should take into account the expected degree of rise and be subject to revision at frequent intervals (perhaps every 15-20 years), as new data on sea-level rise rates are generated. As part of setback guideline revision, an island-wide survey procedure similar to the US coastal survey practice of assigning an Erosion Hazard Area to the coast, based on estimated erosion rates projected 60 years into the future should be implemented (Crowell and Leatherman, 1999).

Sources of beach sand

A research programme to carry out an island-wide survey of the island shelf and upper slope to identify suitable alternative sources of carbonate sand for beach nourishment is needed, as the potential for natural beach replenishment decreases over time. This should be carried out before indiscriminate sand mining develops in response to the needs of the tourist industry.

Satellite based monitoring of reefs

Satellite monitoring of reefs is a fast growing methodology that is applicable to Jamaican island shelf systems, as has been demonstrated in Florida and elsewhere (e.g. Hallock et al., 2004).

CHAPTER 5: OTHER INFORMATION CONSIDERED RELEVANT TO THE ACHIEVEMENTS OF THE OBJECTIVES OF THE CONVENTION

Jamaica received $232,000 from the Global Environment Facility (GEF) in 1998 to undertake its Initial National Communication, with UNDP as the Implementing Agency. The Initial National Communication was completed in November 2000 and submitted to the 6th Conference of the Parties of the United Nations Framework on Climate Change, in The Hague, Netherlands. Jamaica then received an additional US$100,000 from the GEF financing for additional capacity building exercises associated with the initial national communication. The phase two enabling activities, or "top up" began in August 2004 and ended in July 2005.

The phase two capacity building activities for Jamaica targeted three areas:

1. Systematic observation: Analysis of current systematic observation systems and identification of needs;
2. Technology needs assessment: An initial identification of the technological requirements for Jamaica was identified;
3. Public awareness and education: Baseline studies were conducted in order to obtain a good understanding of the level of education and understanding in Jamaica as it relates to climate change.

These activities are described further below. This chapter concludes with a comparison of the initial and second national communications.

5.1 Climate change research and systematic observation systems in Jamaica

From 12-15 April, 2005, an initial assessment of Jamaica's systematic observation systems was conducted in conjunction with the national Meteorological Service. This assessment comprised of interviews with key personnel, as well as visits to a number of locations where systematic observation systems are located.

The assessment focuses on the needs and the requirements of the Meteorological Services, with a view to making recommendations for the improvement of the observation systems in Jamaica. More specifically, the following elements were planned:

(iv) A detailed assessment of the coastal, marine, and hydro meteorological systematic observation systems in Jamaica, describing: the types and locations of the equipment; the agencies responsible for the maintenance of the equipment; the scope of climate related data stored, including climate variables observed; the years for which data is available and frequency of data collection.

(v) An assessment of the current coastal, marine, and hydro meteorological systematic observations systems in Jamaica.

(vi) An identification of the technological and capacity building requirements for the upgrade and improvements of the current systematic observation systems.

It was recommended that 13 automatic weather stations be added to the existing system. Along with some other required upgrades, the total cost of improvements would be US$ 615,853.

5.1.1 Current status of systematic observation systems (April 2005)

The Meteorological Service is organized into three branches:

- The **Administration and Support Services** branch provides efficient and effective administration in the areas of personnel, office management, accounting services, a registry and a library.

- The **Weather** branch is concerned with current weather information and weather forecasting for general dissemination. A continuous hurricane watch is maintained by this branch. Data for forecasts are obtained locally from observation points at the surface and upper air stations as well as from radar stations and internationally through radio-telecommunications links with Miami and Washington and via stationary and polar orbiting weather satellites

- The **Climate** branch manages an island wide network of climatological stations, rainfall stations and automatic weather stations. The branch analyses data generated with a view to monitoring and assessing the climate of the island. The branch also processes requests for clients, which include crop water requirements, design criteria for hydrologists and engineers, and climatological information for resolving legal and insurance claims.

The National Meteorological Centre (NMC)

The forecasting centre of the Meteorological Service is the National Meteorological Centre (NMC), which is located at the Norman Manley International Airport (NMIA). The NMC has a number of instruments and systems which are used for monitoring weather conditions and for communicating with other forecasting centres around the globe.

Through a Small Island Developing States (SIDS) project funded by the Finnish Government and designed to improve meteorological services in Caribbean, the NMC was provided with an International Satellite Communication System (ISCS) to replace the former system, Satellite Transmission for Region 4 (STAR IV) (Figure 5.1). The new Messir equipment is used to transmit weather data via satellite. It can perform numerous analyses and can also manipulate data to yield forecast projections. At the time of the assessment in April 2005, it was reported that the Earthlink equipment, which is used for sending and receiving data to/from the National Oceanic and Atmosphere Administration (NOAA) had a software conflict problem

Figure 5.1: The International Satellite Communication System at the NMC

The Caribbean Radiosonde Network

A Caribbean Rawinsonde Network (CRN) station (the Upper air station) is also located at the airport. The CRN is supplied with spares and equipment by NOAA, which also bears responsibility for equipment maintenance. The CRN releases one hydrogen filled weather balloon each day except during the hurricane season, when two are released day. A microsonde attached to the balloon sends back coded weather information about the upper atmosphere. At the time of the assessment, there were problems with the tracking software that facilitates transmission of data back to the station from the microsonde. This made it difficult to calibrate the system before release, and sometimes resulted in a cancellation of the run all together. The problem was reported to NOAA. Also at the time of the assessment, the hydrogen gas generator needed 3-4 transformers and there was a requirement for filters for water purification. A new solar interruptible power supply was also needed to aid operations during power outages, which NOAA had committed to supplying.

The Automatic Weather Station at NMIA

An automatic weather station is sited adjacent to the runway at the airport and close to the coast (Figure 5.2). The station transmits real-time weather data for aviation purposes. Weather data is reported for the following parameters: rainfall, air, and dew point temperature, relative humidity, wind speed and wind direction, and solar radiation. This data is sent via microwave directly to the forecasting centre and a direct feed is also sent to the air traffic control. At the time of the assessment, pending electrical repairs at the airport were preventing more favourable cabling to the station.

Figure 5.2: Inspecting the Sensors of the Automatic Weather Station at the NMIA

The Doppler RADAR

The Doppler RADAR is located at Coopers Hill, St. Andrew, and was functioning effectively and efficiently at the time of the assessment. It was noted, however, that the radar could provide a number of additional products which could be used to enhance operations of the Meteorological Service. At the time of the assessment, it was stated by the head of the instrument section that there was a need to recalibrate the radar and that the data operator needed a refresher course. There was also a need for a "ground-truthing" of the radar due to a problem with the radar's coverage in north-eastern Jamaica because of a blockage of the line of sight caused by the Blue Mountains. Thus, additional smaller radar (200kw) was needed to cover north-eastern Jamaica to ensure full coverage of the entire island. It was also noted that there was a need for at least 40kw standby power at the site of Coopers Hill for use in emergencies, given the critical role of the radar on such occasions.

Automatic Weather Stations

At the time of the assessment, there were seven automatic weather stations located at (i) Negril Point, Westmoreland, (ii) Montego Bay, St James, (iii) NMIA, Kingston, (iv) Morant Point, St Thomas, (v) Pedro Bank, (vi) Folly Point, Portland and (vii) Discovery Bay, St Ann's. Through the Caribbean Planning to Adaptation to Global Climate Change (CPACC) project, two further stations and tidal gauges were obtained and installed at Port Royal and Discovery Bay (listed above).

Data being generated from the CPACC station in Port Royal was not used as it was close to the automatic weather station at NMIA; the data generated at the airport was used in preference to Port Royal. The station at Port Royal was also in need of repairs at the time of the assessment, as was the CPACC station at Discovery Bay.

Climatological Network

The island's climatological network consists of over 25 climatological stations and nearly 300 rainfall stations. The climatological stations record rainfall, temperature, evaporation and sunshine duration. The network is maintained by the Data Acquisition Section of the Climate Branch. The main instruments used are the Stevenson Screen, thermometers, rain gauges, rainfall loggers, evaporation pans and sunshine recorders.

Currently, the rainfall network covers over 80 per cent of the island's terrain and the climatological stations are located strategically nearest to locations of greatest need for such information. Of the 25 climatological stations, at the time of the assessment eight were out of operation due to equipment failure or damage sustained by the passages of Hurricanes Ivan in 2004 and Emily and Dennis in 2005. Twenty-two rainfall-loggers record rainfall intensity and duration in addition to rainfall amounts the only parameter recorded by the rain gauges.

5.1.2 Data Collection

Prior to 1994, there were no automatic weather stations for the collection of data in Jamaica although the standard meteorological data was always collected. Wind direction, speed, air temperature, relative humidity, atmospheric pressure and rainfall data are collected by the Meteorological Service. Historic data back to 1881 existed, which was based on British plantation data; however a fire in 1993 destroyed much of it and thus the current meteorological database only starts from 1993.

At the time of the assessment, there had been several attempts to recapture data over the previous 10 years but the process was not complete. Some old IBM tapes that may have some data were to be sent to the USA for reading. Some airport data had also been archived at the WMO Region data archiving centre in Arlington, West Virginia, in the USA.

5.1.3 Technological Capacity Needs and Requirements

The 2005 assessment found that the number of automatic weather stations needed to be improved to obtain a comprehensive coverage of meteorological data so as to improve the ability to monitor the micro climates within Jamaica and to understand climate change and its possible impacts in Jamaica. An increase in the amount of weather stations would also aid with provision of agricultural data so that there is better understanding of the climatic conditions. Finally, an increase in the number of automatic weather stations would also assist in providing data to ground truth the Doppler Radar.

It was proposed that 13 more automatic weather stations be added to the current complement of weather stations. The following locations were identified:

- (i) Savannah-La- Mar, Westmoreland
- (ii) Lucea, Hanover
- (iii) Cambridge, St James
- (iv) Black River, St Elizabeth,
- (v) Balaclava, St Elizabeth
- (vi) Alexandra, St Ann's
- (vii) Oracabessa, St Mary
- (viii) Annotto Bay, St Mary
- (ix) Portland Ridge, Clarendon
- (x) Alligator Pond, St Elizabeth
- (xi) Mandeville, Manchester
- (xii) Worthy Park, St Catherine
- (xiii) Ocho Rios, St Ann's

The proposed new automated weather stations would be connected by satellite to ensure effective data reception and permission had been obtained from NOAA to connect the relevant satellite. Additionally, the automatic weather stations installed under the CPACC project would be repaired under the MACC project.

The assessment also identified a need for the maintenance of other critical equipment through the provision of spare parts. For example, to alleviate power problems at relevant offices there was a need for a UPS. A spare processor board was also required for the radar, as the cost of sending one overseas to be fixed was often prohibitive. A full list of the required spare parts needed to assist for the preparation of hurricane season was included in the estimated budget.

Finally, as noted earlier, there was a need for small radar to cover the northeastern area of Jamaica not covered by the Doppler RADAR as well as a need for training to aid with the Doppler Radar operation, so that radar could be recalibrated and used more effectively.

In terms of the improving the Jamaican climatological network, the assessment identified the following equipment needs: (i) an additional 100 rain gauges and measuring cylinders to provide at least 97% coverage of the island; (ii) an additional 40 rain-loggers to complement the rain gauges with intensity and duration information; (iii) fifty full climatological stations for greater spatial coverage – 30 along the coast and 20 at the higher elevations; and (iv) thermometers, evaporation pans, and sunshine recorders for each climatological station.

The total budget for the improvements was estimated at US$ 615,853 (Table 5.1). The project concept is included as an Appendix to this chapter.

Table 5.1: Estimated Budget and Costs for Improving Jamaica's Systematic Observation Systems

Item	**Costs ($US) (2004)**
200kw Radar	400,000
13 Automated Weather Stations and spare tower (shipping)	143,453
Training	10,000
Doppler Radar -Spares	
Signal Processor Board (ESP-7)	18,000
Thyratron	6,500
Thyratron Trigger Module	4,900
Lightning Protection	2,000
Equipment Calibration and Maintenance Training	10,000
Radar Operation and Data interpretation Training	10,000
Upper Air Station	
Filters for Hydrogen Generator Filtration System	500
Standby Power Generator	1,000
Synoptic Sub Station	
Hydothermometer (back-up temperature)	3,000
Aneroid Barometer (atmospheric pressure back-up	1,500
AWS Spares	5,000
TOTAL	**615,853**

5.1.4 Assessment Conclusions

It was concluded that the proposed additional automatic weather stations connected by satellite would have a number of advantages for Jamaica. First, it will improve information on local conditions and could provide important climatic information for a number of uses such as agriculture and disaster management. Second, it would also improve the accuracy of Jamaica's contribution to the international observation systems and databases such as the Global Climate Observing System, NOAA, and the National Hurricane Centre through the tracking of tropical cyclones and the provision of more accurate meteorological data for inputting into Global Circulation Models.

Unlike many countries in the Commonwealth Caribbean, Jamaica has a Doppler RADAR. The Doppler RADAR has a number of uses which can provide a number of opportunities for the Meteorological Service. For example, data can be placed on the internet for public/private access, and the outputs from the Doppler RADAR can also be used in the media for forecasting. There could be possibilities for the Meteorological Service to obtain some revenue using such outputs of the Doppler. Training on the use of the Doppler RADAR should occur in collaboration with the system manufacturer and with NOAA. Also, every effort should be made to rescue relevant data and to improve the current database in which rainfall starts in 1993.

Jamaica should consider approaching an international agency to assist with providing funding to improve the systematic observation systems, such as UNDP, NOAA or WMO. The needs highlighted for the island wide network of rainfall and climatological stations should be addressed urgently since the coverage provided by the stations yields data for multiple uses.

5.2 Jamaica's Initial Climate Change Technology Needs Assessment

5.2.1 Background

The need for technology transfer and environmentally sound technologies has been recognized as critical in averting the threat of climate change throughout the UNFCCC process. Article 4.5 of the Convention states that:

> "*the developed country Parties and other developed Parties included in Annex II shall take all practicable steps to promote, facilitate and finance as appropriate, the transfer of, or access to, environmentally sound technologies and know how to other parties, particularly developing countries Parties, to enable them to implement the provisions of the Convention. In this process, the developed country Parties shall support the development and enhancement of endogenous capacities and technologies of developing country Parties. Other Parties and organizations in a position to do so may also assist in facilitating the transfer of such technologies*."

Through the consultative process, a framework for technology transfer was developed and formally adopted at the Seventh Conference of Parties in 2001 by decision 4/CP7.

A workshop on Technology Needs Assessments and Technology Information for the Caribbean Region was held in October 2003 in Port of Spain, Trinidad and Tobago. The main objectives were to discuss regional concerns and priorities in assessing technology needs, including information tools and resources relevant for the Caribbean region, and to discuss a framework to assist countries in conducting comprehensive technology needs assessments including addressing adaptation issues and concerns. Among the key recommendations and outcomes of the workshop were that adaptation issues are inherently cross-sectoral and are often interrelated with mitigation options and that the Technology Needs Assessment process and activities should not be conducted in a vacuum but ensure links with national development priorities and needs.

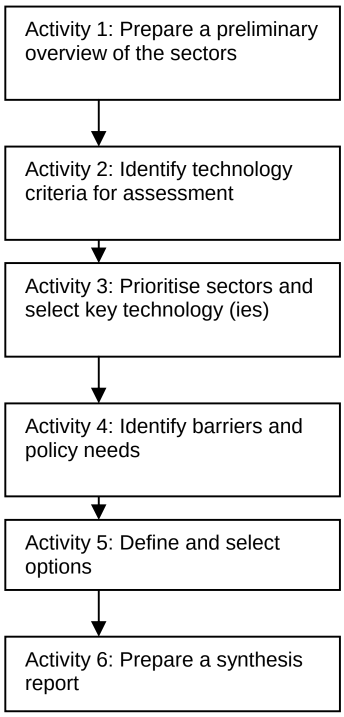
5.2.2 The Technology Needs Assessment Process

Technology transfer is concerned with the flow of experience, know how, and equipment between and within countries. Decision 4CP/7 noted that technology transfer has five key elements connected within an integrated framework. These elements are:

(i) the technology needs assessment,
(ii) improving access to technology information,
(iii) improving and strengthening local capacity,
(iv) creating enabling environments, and
(v) instituting technology transfer mechanisms.

A technology needs assessment process is defined as a set of country-driven activities that identify and determine national mitigation and adaptation technology priorities, which can form the basis for a portfolio of environmentally sound technologies projects and programmes. To conduct the technology needs assessment, Jamaica used a six-step process outlined by UNDP (Figure 5.3).

Figure 5.3: UNDP Technology Needs Assessment Process



Activity 1 is a preliminary overview or assessment of the sectors which are to be analyzed. The assessment involves collecting and analyzing the various data and information which exists on this sector, so that a comprehensive overview of the sector is complete.
Activity 2 involves the identification of technology for criteria for investment. This depends on a number of factors as it relates to the technology. Key questions such as the contribution to development goals and the possible market potential of technology have to be considered.
Activity 3 is the identification of priority sectors and key technologies, which will be based on the key criteria for the technology and the importance of the sector. The availability and the possible access to the technology should be considered.
Activity 4 allows the identification of barriers to applying specific technologies, and the identification of policy needs which are required to improve technology transfer.
Activities 5 and 6 involve selecting technological options for the short and long term, and the preparation of a report for review. The entire technology needs assessment process should involve stakeholder consultation and engagement along with barrier analysis.

For Jamaica, the technology needs assessment process consisted of a series of expert workshops with key sectoral experts present to discuss issues relating to technology in Jamaica. The first workshop focused on mitigation and energy issues, while the second workshop looked at adaptation issues as they relate to the coastal zone and water sectors in Jamaica. Both workshops used the initial national communication of Jamaica as the document of reference.

5.2.3 Mitigation Technologies for the Energy Sector

Greenhouse Gas Emissions/Current Situation (2005)

The Initial National Communication of Jamaica was submitted in November 2000. The GHG inventory was a key component. GHG emissions and removals by sinks were calculated for the base year 1994 utilizing the 1996 Revised IPCC Guidelines. In 1994, Jamaica emitted 8,585 gigagrams (Gg) of carbon dioxide (CO_2) and 58.47 Gg of methane (CH_4) (Table 5.2).

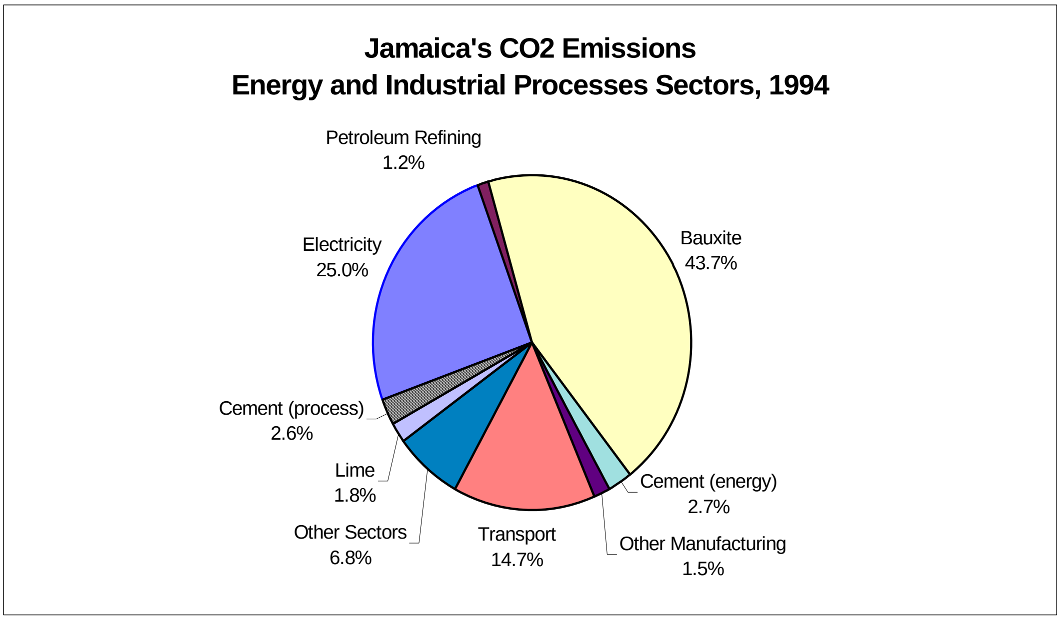
The majority of CO_2 emitted in Jamaica is as a result of fossil fuel combustion for energy, with the manufacturing industries and the construction sector being responsible for over 4,000 Gg of carbon emissions. Figure 5.4 shows that 43.7% of the emissions in the energy and industrial process sectors are due to energy combustion in the bauxite industry.

Table 5.2: Summary of Greenhouse Gas Emissions of Jamaica (Gg) (1994)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Emissions	CO_2 Removals	CH_4	N_2O
Total National Emissions and Removals (Gg)	**8,585**	**-167**	**58.47259**	**344**
1 Energy	**8,182**	**0**	**1**	**0**
A Fuel Combustion (Sectoral Approach)	8,182		1	0
1 Energy Industries	2,245		0	0
2 Manufacturing Industries and Construction	4,111		0	0
3 Transport	1,257		0	0
4 Other Sectors	586		0	0
5 Other (please specify)	-18		0	0
B Fugitive Emissions from Fuels	0		0	
1 Solid Fuels			0	
2 Oil and Natural Gas			0	
2 Industrial Processes	**403**	**0**	**0**	**0**
A Mineral Products	403			
B Chemical Industry	0		0	0
C Metal Production	0		0	0
D Other Production	0			
E Production of Halocarbons and Sulphur Hexafluoride				
F Consumption of Halocarbons and Sulphur Hexafluoride				
G Other	0		0	0
3 Solvent and Other Product Use	**0**			**0**
4 Agriculture			**43**	**343**
A Enteric Fermentation			36	
B Manure Management			7	4
C Rice Cultivation			0	
D Agricultural Soils				339
E Prescribed Burning of Savannas			0	0
F Field Burning of Agricultural Residues			0	0
G Other (please specify)			0	0
5 Land-Use Change & Forestry	**(1) 0**	**(1)**	**0**	**0**
A Changes in Forest and Other Woody Biomass Stocks	(1) 0	(1)		
B Forest and Grassland Conversion	88		0	0
C Abandonment of Managed Lands		(		
D CO_2 Emissions and Removals from Soil	(1) 0	(1)(		
E Other (please specify)	0	(	0	0
6 Waste			**14.40987**	**0**
A Solid Waste Disposal on Land			14.408181	
B Wastewater Handling			0.0016889	0
C Waste Incineration				
D Other (please specify)			0	0

Source: Jamaica's First National Communication to the United Nations Framework Convention on Climate Change

Figure 5.4: Carbon Dioxide Emissions from Energy and Industrial Processes Sectors (1994)



Source: Jamaica's First National Communication to the United Nations Framework Convention on Climate Change

Currently in Jamaica, there was 780 Megawatts (MW) of installed electricity generating capacity, of which 5.6 per cent was generated from renewable energy sources. The Wigton Wind Farm in Manchester provides 20.7 MW, while other sources of renewable energy were from the use of bagasse and small-scale hydro-electricity generating plants.

Jamaica is not a producer of fossil fuels and is therefore heavily dependent on the importation of fuels to meet its energy needs. Currently 65% of foreign exchange earned was spent on imported fuel, which amounted to about 15 per cent of Gross Domestic Product. Thus, a reduction in the amount of fossil fuel imported would directly aid in improving the Jamaican economy. Table 5.3 shows the importation of petroleum products for 2003, whilst Table 5.4 shows the consumption of petroleum products for 1998 and 2003.

Table 5.3: Importation of Petroleum to Jamaica (2003)

Items	Volume (million bbls)	Value (US$ Million)
Bauxite and Alumina	9.03	212.3
Marketing Companies	3.03	133.0
Petrojam-Crude Imports and Refined Products	15.04	467.7
Total	**27.10**	**813.0**

Source: Draft Power/Electricity Policy for Jamaica 2004, Ministry of Commerce, Science and Technology

Table 5.4: Fuel Consumption by Various Sectors (1998 and 2003)

Activity Sectors	Million bbls 1998	Percentage	Million bbls 2003	Percentage
Rail and Road Transport	5.75	25.00	6.07	23.5
Shipping/Aviation	1.60	7.00	2.01	7.8
Electricity Generation	5.12	22.00	6.47	25.1
Bauxite/Alumina	8.67	38.00	9.54	37.0
Cooking	0.84	4.00	0.90	3.5
Manufacturing/Processing	0.64	3.00	0.53	2.1
Other	0.19	1.00	0.25	1.0
Total	**22.81**	**100.00**	**25.78**	**100.0**
Non-bauxite/bunkering	12.54	55.0	14.23	55.4
Bauxite/bunkering	10.27	45	11.55	44.6

Source: Draft Power/Electricity Policy for Jamaica 2004, Ministry of Commerce, Science and Technology

According to Table 5.3, US$212 million of oil was imported (in 2003?) for alumina and bauxite operations, US$133 million imports by the marketing companies and US$467 million by the Petrojam oil refinery. The 9.03 million barrels of oil imported for the alumina sector in 2003 was at a cost of US$24 per bbl. Crude prices for 2003 averaged US$28 per bbl compared to US$34 for finished products. The average price of oil imports was US$29 per bbls in 2003. Between 1998 and 2003, the cost of imported oil for the alumina sector went up from US$91 million to US$212 million -- an increase of more than 130 per cent.

Fuel imports can be broken down into two basic categories. The first category consists of the bauxite/alumina/shipping/aviation sub-sectors, which are export-based, while the second category of electricity generation/road transport is import based. Thus, the implications for the economy are slightly different. Increased alumina production will results in increased oil consumption. Fuel oil for the bauxite/alumina sector is paid from the industry's export earnings, and hence there is little drain on the foreign currency reserves. Fuel oil for electricity generation/road transportation/cooking is import based and thus will have an effect on foreign currency reserves.

The increased electricity consumption in recent years has come mainly from higher quality of life; including the wider use of electrical equipment and devices in homes and factories such as air conditioners, television sets, computers, washing machines, rather than from expansion of the industrial base.

There has also been a rapid expansion in oil consumption for local transportation. This took place, immediately after the motor vehicle liberalization policy in the mid 1990s. The transportation share of oil consumption increased from 16 per cent in the early 1990s to 25 per cent in 1998. There are now more vehicles are on the road, and this accounted for the increased oil consumption, rather than higher consumption by existing vehicles. With the reduction in the age of second hand vehicle imports in the latter part of the 1990s, the rate of used vehicle additions has slowed. The fuel efficiency of the vehicle imported has also increased. The result is that the rate of increase for fuel oil consumption for local transportation has slowed.

Jamaica, unlike many countries in the English speaking Caribbean, has a liberalized energy market. This allows for auto generators or self generators such as the sugar factories and alumina plants to sell excess capacity to the Jamaica Public Service Company Limited (JPSCo) as if they are independent power producers. They can also wheel electricity from their own generation plant along JPSCo's transmission and distribution network to owned end use points, so long as no third party sale is involved. Electricity, however, remains the most important area in terms of opportunity to reduce the imported energy bill.

Jamaica had a well established energy policy at the time of the assessment (a new policy for 2009-30 has just been adopted). The objectives of the energy policy of Jamaica were as follows:

a) To ensure stable and adequate energy supplies at the least economic cost in a deregulated and liberalized environment
b) To diversify the energy base and encourage the development of indigenous energy resources where economically viable and technically feasible; and ensure the security of energy supplies
c) Encourage efficiency in energy production, conversion and use with the overall objectives of reducing the energy intensity of the economy
d) Complement the country's Industrial Policy recognizing the importance of energy as a critical in out to industrial growth and stability
e) Minimize the adverse environmental effects and pollution caused by the production , storage, transport and use of energy, and minimize environmental degradation as a result of the use of fuel wood and;
f) Establish an appropriate regulatory framework to protect consumers, investors and the environment.

In order to achieve the objectives of the energy policy, an enabling environment was created to:

a) Encourage private sector participation and investments through a policy of divestment and an appropriate regulatory framework conducive to new investment
b) Promote the development of indigenous energy source where appropriate technically and economically feasible
c) Encourage energy conservation/efficiency on the supply side as well as demand side management
d) Fully protect the environment while ensuring that adequate energy supplies are available to the country and to sustain the desired rate of economic growth, and at the same time stimulate industrial development by encouraging synergies from co-generation; and
e) Maintain appropriate institutional arrangements to ensure that the stated objectives achieved.

The energy policy of Jamaica was designed to continue to foster, facilitate and encourage the development of all new and renewable energy sources, improve information dissemination with regards to energy conservation systems and promote and support Demand Side Management. With regards to economic incentives, the energy policy notes that the tax applied on energy conservation equipment and materials and supplies will be such that it will ensure that the items involved are available to the public and that the consumers will be encouraged to invest in the most efficient end use device or technology.

Criteria for Mitigation Technologies

A number of issues were considered with regards to criteria for the transfer and development of technologies for mitigation for Jamaica. These included the overall integration with the current energy policy, and the linkage to development goals. In order for a technology to be suitable for Jamaica, it was agreed there a number of key criteria which have to be met. These are:

(v) affordability and low cost,
(vi) environmental and economic impact,

(vii) social acceptability, and
(viii) job creation potential.

The identification of these key criteria was done utilizing expert judgment and stakeholder analysis. It was noted that any technology which is to be transferred to Jamaica should aid in reducing the amount of foreign exchange which is utilized to purchase energy, in addition the technology should be durable, be commercially proven and aid in the development of Jamaica. Further, the proposed technology should be in line with future projected energy scenarios. One possible scenario sees the expansion of capacity from the current 780 MW to 1250 MW by 2015. Table 5.5 shows the possible fuel sources which could be used to meet the scenario.

Table 5.5: A Possible Future Energy Scenario for 2015

Fuel Sources	MW
Heavy fuel oil and diesel	380
Natural gas and coal	700
Wind	70
Hydropower	35
Solid waste	10
Bagasse and fuelwood	35
Ocean energy	10
Solar photovoltaics	0.2
Fuel cells	9.8
TOTAL	**1,250**

<u>Mitigation Technology Requirements</u>

Natural Gas Technology

Natural gas is the cleanest burning fossil fuel, and is available for transport in the form of liquefied natural gas (LNG) or compressed natural gas (CNG). Since the 1990s, natural gas has been one of the fastest growing sources of energy for electricity generation, with combined cycle gas technology increasing levels of competition and efficiency. The problem for Jamaica as a SID is that LNG is far away from the source. Natural gas has to be transported in specialized LNG ocean tankers and thus a terminal to receive natural gas is required so that Jamaica could benefit from its importation. This has been identified as a priority for Jamaica. There are plans for the construction of a natural gas terminal to import 1.1 million tonnes per year of LNG. Given the considerable energy requirements of bauxite industry, this natural gas will be used to generate electricity which will be shared among the major bauxite companies to remove their dependence on fuel oil.

Technology to extract CH_4 from landfills and generate electricity is also required and is a priority. This has the potential to generate at least 10MW of electricity in Jamaica and initial plans are in place to pursue the generation of electricity from landfill gas

Transport

With increase in the number of motor vehicles in Jamaica, the transport sector was also highlighted as priority sector where new technologies need to be applied. There is a need to examine the mass transit possibilities in Jamaica; especially the possibilities for light rail transit need further consideration.

Given the large amounts of foreign exchange which is spent on the importation of gasoline for vehicles, there is a need to look at alternative fuels and vehicles for Jamaica. CNG can be used in vehicles, and there are a number of manufactures of natural gas engine vehicles which could be used in Jamaica. Utilizing natural gas vehicle in Jamaica would have a number of benefits including promoting energy security, and reducing the amount of particulate matter and NOx which are emitted. Fuel cell vehicles could also be utilized in Jamaica, but there are a number issues related to fuel storage and facilities which would need to be addressed, such as the increase in the number of retail points.

Diesel is cheaper than gasoline and there have been many developments in diesel engine technology which Jamaica could benefit from. An increase in the number of vehicles utilizing low emission diesel engines would be beneficial in Jamaica. Electric vehicles and hybrid vehicle would also be desirable in Jamaica, as these vehicles have little emissions and will help reduce the dependency on gasoline.

Renewable Energy Technologies

With the increasing amount escalating fossil fuel prices and the ever increasing amount of foreign exchange being spent on fossil fuels, the development of a vibrant renewable energy sector will help in improving energy independence. Jamaica, like many other SIDS, has an abundance of resources for renewable energy projects. The value of renewables lies in their ability to respond simultaneously to the two challenges which confront the energy sector, which are sustainable development, and security and economic growth. Renewable energy technologies options for Jamaica are highlighted below.

- *Wind Energy*: Jamaica already has a 20.7MW wind farm. Jamaica also has several other sites where the wind is in excess 8 metres per second and thus is suitable for the generation of electricity by wind. Generation of electricity by wind is very competitive with conventional mechanisms. Wind has been identified as priority technology for Jamaica given that it is proven and the wind resource is free.

- *Small Scale Hydro Power:* Jamaica was one of the first countries outside of the United Kingdom to install a hydro plant, just outside of Spanish Town in the 1890s. Currently there were nine hydro plants ranging from 0.2MW to 6MW with an overall generating capacity of 23 MW installed in Jamaica, and potential for the installation of at least an additional 30 MW of hydro capacity. With the continued increase in oil prices world wide, hydro power has become a priority as it now more competitive. There are small specialized hydro power technologies which are suitable for Jamaica.

- *Cogeneration and Biomass:* With the changes in the international market and the end to preferential treatment for sugar, alternative uses have to be found for sugar cane. Jamaica has vibrant sugar industry and currently there were seven sugar mills generating around 30MW of power from bagasse for own use. There is considerable potential to improve cogeneration possibilities in Jamaica. Cogeneration offers the opportunity to meet multiple objectives: improving energy efficiency and integrating energy policy into the industrial development policy. Cogeneration technologies characterized by high output ratios of electricity to steam for example, reciprocating internal combustion engines and fuel cells make it possible for cogeneration to play an important role in the power generation and energy efficiency in Jamaica.

The seven sugar factories could meet all their energy needs, while supplying excess power to the national grid from cogeneration renewable resource. Some initial estimates note that between 80 to 100MW of additional capacity is feasible, and this would allow the sugar industry to export 70 MW of power in the crop season to the national grid and provide significant foreign exchange savings to the country while contributing to the commercial sustainability of the industry.

Ethanol can also be produced by the sugar cane industry in Jamaica, thus adding to the products which the sugar cane industry can provide. Ethanol can be used for a variety of purposes in Jamaica, these include replace octane enhancers in gasoline, as a transport fuel as is done in Brazil. The ethanol which is produced can also be exported. Technology for ethanol production is therefore a priority. Currently, there was a 40 million gallon ethanol production plant being commissioned in Jamaica.

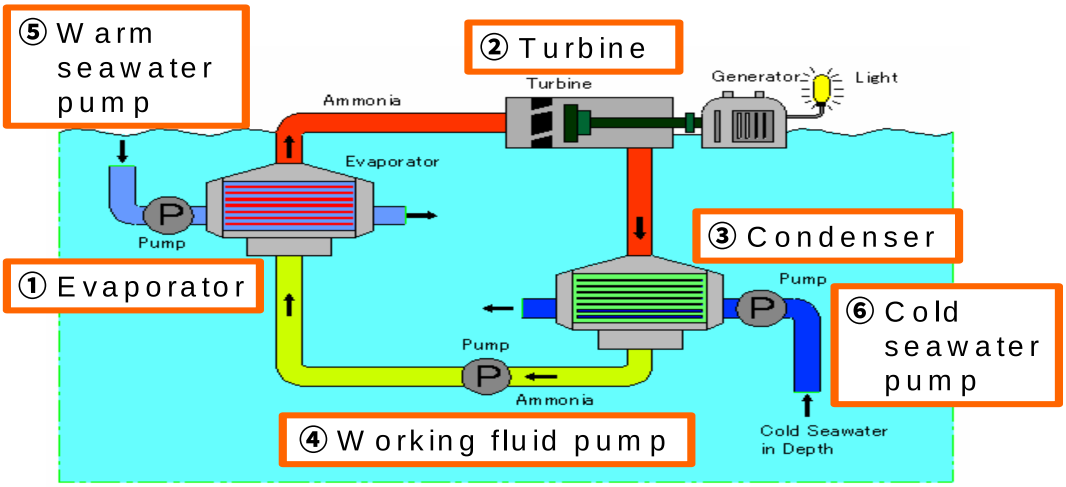
- *Solar Energy:* Jamaica is ideally suited for the application of solar technologies. Many areas in Jamaica have solar insulation of 8kWh per sq. metre per day, which is excellent for utilizing solar energy for the supply of electricity.

  While there are a number of photovoltaic systems scattered across the island, there is room for improvement with regards to solar energy in Jamaica. There some street lighting systems which use photovoltaics, but there is a need for more photovoltaics to be used throughout the country. Some other islands in the region have developed solar hot water heating technologies and these have been transferred to Jamaica. There however a need for the more widespread use of these systems in Jamaica. Economic incentives might be required.

  The potential for solar crop drying has not been fully realized in Jamaica although it is a means of preventing spoilage which affects as much as 30 per cent of crop production. Crops such as bananas, papaya, sorrel, sweet potato, yam, ginger, nutmeg, pimento, grasses and leaves can be dried by solar dryers, which range from the simple wire basket dryer to approximately two square metres of roof solar collectors.

- *Ocean Thermal Energy Conversion (OTEC):* OTEC is an energy source that basically utilizes the differences in the temperature gradients in between the warm surface water and the cold deep waters to drive a turbine to provide electricity (Figure 5.5). OTEC uses only seawater as energy resource. It provides an inexhaustible energy resource which is stable, with zero GHG emissions. OTEC. There are number of deepwater sites around Jamaica which can be used for OTEC. OTEC technology is suitable for Jamaica, and there are many commercial spins such as mariculture.

Figure 5.5: The Principle of OTEC



<u>Energy Policy, Efficiency, Conservation and Demand Side Management</u>

Jamaica, unlike many countries in the Caribbean, has a fully liberalized energy sector. Thus, Jamaica has long recognized the need for effective energy efficiency measures. The Jamaican Public Service Company (JPSCO) has a demand side management programme which was developed through a Global Environmental Facility (GEF) demonstration project.

At the time of the assessment, future government policy with regards to energy efficiency and conservation was planned around:

- an Energy Efficiency Building Code,
- a Home and Small Business Energy Efficiency Scheme,
- an Energy Efficiency Commitment Scheme for large Commercial and Industrial Users,
- a Public Sector Energy Efficiency Programme,
- an Energy Efficiency Monitoring and Rating Programme,
- an Efficiency and Renewable Energy Fund,
- a Special Tax Incentive Package for Energy Efficiency Products and Investments, and
- an Energy Efficiency Advice and Public Education programme.

The policy was to be built around the use of energy efficient devices and equipment and proper control and maintenance of energy consuming equipment. Energy audits were also planned for many commercial and industrial users.

A new demand side management programme was also under consideration, developed jointly with JPSCO and the government, with a possible target of 3 per cent reduction in demand over 5-7 years or 20 MW of capacity. JPSCo may be provided with a mechanism to recover through the tariff base or energy fund investments made on demand side management measures.

5.2.4 Technologies for Adaptation in the Coastal Zone and Water Resources Sectors

Current Situation (2005)

Coastal zones were identified as a critical sector for Jamaica in the Initial National Communication. The National Environment and Planning Agency (NEPA) reported that 90 per cent of the GDP was produced within the coastal zone. Jamaica's coastline is approximately 886km in length and has diverse ecosystems, including sandy beaches, rocky shores, estuaries, wetlands, sea-grass beds and coral reefs. Table 5.6 shows the different natural regions along which the coastal zones of Jamaica can be divided.

Table 5.6: The Various Natural Regions within the Coastal Zone of Jamaica

Natural Region	Natural Features	Characteristic Developments
Negril	Coastal sand barrier and morass	High density tourism, plantation, mixed farming
Negril	Cliff and hill coast	
South-western coastal plain and wetlands coast	Savannah La Mar – Surinam Quarters – Black River. Sandy bays coastal barriers, patch and fringing reefs	Livestock, mixed farming, fishing, low density tourism, port facilities
Pedro Plains – To Hill	Hill and cliff coast with minor beaches and limited fringing reefs	
Long Bay Hill and Vere Plains	Wetland coast with fringing reefs between Rocky Point and Jackson Bay	
Portland Scrubland Ridge and Portland Bight	Low cliffs, hill and low plains wetland coast with few sand beaches, scattered fringing reefs and patch reefs	Fishing, low density tourism, port facilities
Hellshire Scrubland hills and bay	Low cliff and sandy erosive barrier and lagoon with poor mangrove, patch reefs and limited fringing reefs	
Kingston	Domestic area	High density urbanization, tourism port facilities
St David bush hill	Bush hill and gravel beach system from the Palisadoes to Yallahs	
The Morant River gravel beach system	Low Hills with cane fields, a wide wetland without major drainage channels, very long sand beaches in the western part and a wide coral zone.	Plantations mixed farming, gravel excavation
The Morant Point Great Morass	Low hills with cane fields, a wide3 wetland without major drainage channels, very long sand beaches in the western part and a wide coral zone.	
The Eastern Coast	Hilly, cultivated, open rocky cliff coast with few small bays and sand beaches except Long Bay and with scattered nearshore fringing reefs	
The North-Eastern Portland Coast	Mixed wood/cultivated cliff coast with many narrow bays and pocket beaches	Plantations, low density tourism, port facilities

Natural Region	Natural Features	Characteristic Developments
The Western Portland St Mary Coast	Cultivated hills with large open bays with partly unstable gravel beaches and in some section a wide fringing reef zone	
St Mary Coast	Hilly, steep rocky cliff coast with few bays and partly well developed fringing reefs	Low/high density tourism, mixed farming
The straight northern mixed coast	The mainly cultivated lowland coast from Oracabessa to Silversands with few bays scattered white sand beaches and wetlands and widely distributed coral reefs. The hilly woodland coast from Silver Sands to Falmouth with a narrow shore terrace with lagoons. The Falmouth lowland/wetland coast. The St James low, coastal foothill terrace, open coast with minor white sand beaches and nearshore fringing reefs	Mixed farming low density tourism
The Montego Bay	Dominated by coastal constructions	High density tourism urbanization, mixed farming, port facilities
The Hanover Coast	The northern rocky cliff coast with coves and limited fringing reefs: the northwestern coast with large coves, wetland and fringing and patch reefs.	

Source: Jamaica First National Communication to the United Nations Framework Convention on Climate Change

Critical infrastructure is located within Jamaica's coastal zone, including port facilities, tourism resorts, and dense population centres. The coastal zone of Jamaica is thus very susceptible to sea level rise, which would cause increased beach erosion rates and higher incidences of coastal flooding. Permanent inundation could occur in some areas.

Climate change could also compound and amplify the effect of tropical storms and hurricanes. Jamaica has suffered in recent times from extreme weather events, with Hurricanes Dennis and Emily affecting the island during 2005. During September 2004, Hurricane Ivan struck Jamaica causing approximately US$580 million dollars worth of damage through direct damage and indirect losses. The initial national communication noted that the cost estimated by the IPCC in 1990 to protect Jamaica from one metre of sea level rise to be US$462 million. The potential for damage from climate impacts to the biodiversity of the coast and the coastal infrastructure is very high. The economic value of all the resources in the coastal zone will also be adversely impacted as a result of sea level rise and a changing climate. A large percentage of Jamaica's population (approximately 25 per cent) is concentrated near to the coastline, thus a rise in the sea level will cause a displacement with regards to coastal settlements.

Jamaica's freshwater reserves come from a variety of sources. There are surface sources in the form of river and streams, and underground sources in the form of wells and springs. There is some rainwater harvesting in Jamaica, however groundwater meets most of the water demands in Jamaica. The initial national communication noted that water demand distribution in Jamaica is based on the location of irrigated lands, population concentrations, tourism development, and other water consuming industries. The demand in the south is high, due to the extensive agriculture in the areas of little rainfall. Bauxite and sugar cane processing industries located in the south also consume large amounts of water. Demand in the north of Jamaica is lower because there is greater rainfall and less cultivable land.

Changes in rainfall patterns could cause a decreased surface and groundwater supplies. Climate change will present additional water management challenges in Jamaica. There are predictions of increased short intense rain events under certain climate change scenarios. This would cause low percolation and recharge of aquifers and high run off. Reductions in rainfall as a result of climate change will affect water sources and supply. The reductions in rainfall will mean that less water will be available for domestic demand. Decreasing rainfall will mean that there will be an increase in irrigation requirements for agriculture. Water resources are important for all aspects of the economy; thus with a changing climate, key sectors such as tourism, and agriculture will be affected negatively.

Criteria for Technologies for Adaptation

A number of issues were considered when criteria for the transfer and development of technologies for adaptation were considered. Stakeholder consultations and expert judgment were used to determine the criteria. It was noted that technologies for adaptation should be: cost effective, proven, flexible, aid in vulnerability reduction, and easy to use. Technologies for adaptation should also look at technologies in the broadest sense.

Adaptation Technology Requirements

A number of technologies for adaptation were suggested to aid in improving coastal zone management, in order to reduce the overall vulnerability of the coast to sea level rise. It was noted that beach protection measures such as groynes and revetments will be required. However, the reinstating of the tidal gauge network was highlighted as a priority for obtaining data, coupled with improved data collection for the geographic information system. Improvement in the geographic information systems will aid in planning and project designs, thus ensuring that vulnerability reduction will occur. Beach profiling also needs to be expanded in Jamaica to aid the improved data collection. The regeneration of mangroves was another a priority identified.

In the water sector, the following needs were noted: an improvement and rationalization of the hydrometric network; additional river gauges and more automatic weather stations to aid in data collection and planning to reduce vulnerability; additional flood warning systems; and additional software such as waterware, riverware, and mikebasin to aid in improvement of water management.

5.2.5 Barriers to Technology Transfer in Jamaica

The main barrier to the transfer of technology to Jamaica is the high initial capital cost of technologies. There is a need for flexible financial measures in order for new technologies to be adopted.

Attitudes, perceptions, and lack of information were also highlighted as a key barrier. In particular, lack of understanding about specific technologies and lack of political will prevent the transfer and adoption of potential technologies.

Lack of data is a constraint, particularly with regards to vulnerability issues which prevents adoption and applications of technologies for adaptation. The lack of a central decision making entity to handle issues with regards to technology was also noted as a barrier.

5.2.6 Conclusions and Recommendations

This technology needs assessment was an initial examination; the technology needs assessment process should be continued and there is a need to revisit this issue. Technology issues as they relate to agriculture have not yet been examined and an in-depth analysis of the technology requirements for the agricultural sector is needed, given the critical role of the sector to the Jamaican economy. There should also be a specific consultation with the industrial sector so that the specific technologies for industry can be identified and transferred.

Public education, information and awareness with regards to new technologies need to be improved. It was highlighted that a biogas project in Jamaica was not very successful as a result of a lack of effective public education initiatives. Education and sensitization to new technologies should be targeted at every level of the society, and perhaps there is a need for a specific education and sensitization programme specifically tailored for policy makers.

There may also be a need for a clearinghouse with regards to technology to be put into place, although raising awareness with specific stakeholders about the UNFCCC's TT: Clear website would aid information-sharing about potential useful technologies.

Improvements in the data which is collected was highlighted as concern by many stakeholders. However, it was agreed that the lack of data should not prevent projects from proceeding. The Kingston Area is particularly susceptible to sea level rise, and it was noted that a project looking at the vulnerability of the area should be developed.

Natural gas technology has been highlighted as a priority for Jamaica, with a proposal for the construction of a natural gas terminal. Jamaica should also exhaust all of its hydropower potential, and establish more wind farms. This would help reduce the dependency on fossil fuels and save valuable foreign exchange. OTEC technology was highlighted as an area for further investigation, with the possible identification of sites. Many stakeholders identified the need to encourage Jamaican entrepreneurs and business into the energy sector but noted this would require financial incentives – for entrepreneurs and consumers alike – to use renewable energies rather than standard technologies.

5.3 Capacity and Technological Requirements, Public Awareness, and Second National Communications

As part of the "top-up" enabling activity, a number of baseline studies were conducted to obtain a better understanding of the level of education and understanding about climate change of Jamaican citizens. A number of activities were undertaken, including:

(v) *An in house focal point workshop on the Jamaica Phase Two Top Up activities*. The purpose of the workshop was to sensitize the relevant persons within the Meteorological Service to the project and the possible outputs.

(vi) *A project launch workshop*. The objectives of this workshop were to: 1) aid in reconvening the National Implementation Coordinating Unit for climate change in Jamaica and 2) launch phase two by informing participants about climate change, regional concerns, climate change scenarios, and alternative energy options for Jamaica.

(vii) *A Climate Change Symposium*. Participants were sensitised to international issues related to climate change, particularly the 10th Conference of Parties of the UNFCCC and the effect that climate change could have on energy, water resources, coastal resources and biodiversity.

(viii) A climate change public education and awareness survey

(ix) An *examination of the systematic observation systems* and needs of the Meteorological Service of Jamaica.

(x) An *adaptation and mitigation technology needs assessment*.

Another focus of the Phase 2 project was to identify preliminary areas for the design of the Jamaica's Second National Communication to the UNFCCC. The identification of future capacity needs as they relate to climate change was also a critical component of the project.

Overall, the activities aided in facilitating national networks on climate change and promoting the integration of climate change concerns into the national development planning dialogue.

5.3.1 Capacity and Technological Requirements for Jamaica

The preparation of the Initial National Communication of Jamaica identified a number of capacity constraints and difficulties. These included:

(i) Inappropriate methodological framework (IPCC 1996 Revised Guidelines) for assessing the GHG emissions of small island states;

(ii) Lack of expertise/knowledge in implementing test methodologies and establishing baseline conditions;

(iii) Lack of country-specific data and inadequate/inappropriate statistics for simulation models;

(iv) Difficulties in identifying experts for multi-disciplinary teams to undertake cross-sectoral assessments;

(v) Very low public awareness of climate change issues and inadequate sensitization to anthropogenic factors that exacerbate climate vulnerability;

(vi) Inadequate private sector support; demonstrated lack of commitment to climate change issues;

(vii) Absence of strong academic, research or regional environmental institutions to provide substantive support in the process.

Some of these capacity constraints had started to be addressed at the time of the assessment. Three regional projects -- CPACC, the Adapting to Climate Change in the Caribbean Project, the Mainstreaming Adaptation to Climate Change -- and the establishment of a regional climate change centre are aiding improved capacity in the Caribbean. Additionally, many of the technical issues raised had started to be addressed. For example, one project in the Caribbean was examining the downscaling of global climate models, thus aiding the provision of data for simulation models.

Among the key difficulties remaining were low public awareness on climate change issues and inadequate private sector support.

Capacity building on climate change is critical for Jamaica. Capacity building in the right areas will aid Jamaica in not only implementing the Convention and its obligations, but ensuring that the country makes the right decisions with respect to climate change.

A GEF-funded National Capacity Self Assessment (NCSA) project in Jamaica examined issues related to capacity issues and climate change. A number of skills were identified in the NCSA report to address the physical, social and economic impacts of climate change and are reproduced in Table 5.7.

Table 5.7: Matrix of Required Skills for Climate Change

Skills Required for Responding to Economic Impacts		
Area of Expertise	Relevant Sector	Requirement
Human/Economic Geographers,	All Sectors	Assessing economic impacts
Resource/Environmental Economists,	All Sectors	Assessing the economic cost to the environment
Environmental Scientist,	All Sectors	Assessing the scientific impact to the environment
Resource Managers,	All Sectors	Managing of resources
Skills Required for Responding to Physical Impacts		
Area of Expertise	Relevant Sector	Requirement
Coastal zone management specialists	Coastal Zone	Planning physical use of coastal zone by assessing vulnerabilities & adaptation options
Coastal managers	Coastal Zone	Enforcement of adaptation options for physical use
Physical oceanographers	Coastal Zone	Assessing the vulnerability of coastal seabed
Marine/fisheries scientists	Coastal Zone	Vulnerability assessments of marine ecosystems and marine life
Hydrologists	Water Resources	Monitoring and predicting availability of water resources
Water resource specialists	Water Resources	Developing strategies for use of water resources based on climate change considerations
Hydro-geologists	Water Resources	Assessment of aquifers vulnerabilities and options to mitigate them
Agro-climatologist	Agricultural	Provision of long term predictions for crops
Agro-meteorologists	Agricultural	Provision of short term predictions to agricultural sector
Skills Required for Responding to Social Impacts		
Area of Expertise	Relevant Sector	Requirement
Social scientists	All sectors	Assessing impacts on society
Population and cultural geographers	All sectors	Impact on population and culture
Social anthropologists	All sectors	Relating past impacts to future planning
Human security	All sectors	Planning for response to impacts on human well being
Livelihood specialist	All sectors	Assessments on impact on well being
Sustainable development specialists	All sectors	Planning for response to impacts

The NCSA also identified and prioritised key climate issues, and then identified the capacity constraints related to those climate issues. Tables 5.8 and 5.9 present these results.

Table 5.8: Issues Prioritization Matrix

Issue	Scale of problem	Level of concern	Ability to adequately address issues	Priority Ranking*
Public Awareness & Public Education	National	High	Low	1
Assessment of Vulnerability of Coastal Zone	Local	High	Low	2
Formulation of Adaptation Measures	Local	High	Low	2
Integration of Climate Change Concerns into National Policy	National	High	Low	3
Assessment of vulnerability of Water Resources	National	High	Low	2
Vulnerability of agricultural sector	National	Medium	Low	4
Vulnerability of health sector	National	Medium	Low	4
Develop National Action Plan	National	High	Low	1
The Clean Development Mechanism	National	High	Medium	3
**1 = most severe problems, 2 = next most severe, etc*				

Table 5.9: Capacity Constraints Matrix

Priority Issues	Capacity Constraints		
	Individual	**Institutional**	**Systemic**
Public Awareness & Public Education	Staffing level of Meteorological Service need to be expanded to adequately address issue	No climate change unit exists	Due to Budgetary constraints no adequate funding for comprehensive campaign
Develop National Action Plan	Temporary loss of key climate change personnel at Meteorological Service to studies	Climate Change activities are additional duties shared with normal functions of Focal Point	Need for a national climate change committee to guide process Need to source funding for process.
Assessment of Vulnerability of Coastal Zone	Training required in vulnerability assessments and adaptation measures	Adequate funding will be required for assessments	Vulnerability assessments not part of education curriculum
Assessment of vulnerability of Water Resources	Training required in vulnerability assessments and adaptation measures	Adequate funding will be required for assessments	Vulnerability assessments not part of education curriculum
Integration of Climate Change Concerns into National Policy	Low level of understanding by relevant personnel	Low priority given to issue	Low level of priority given to issue
Vulnerability of health sector	Training required in vulnerability assessments and adaptation measures	Adequate funding will be required for assessments	Vulnerability assessments not part of education curriculum
Vulnerability of agricultural sector	Training required in vulnerability assessments and adaptation measures	Adequate funding will be required for assessments	Vulnerability assessments not part of education curriculum
Clean Development Mechanism	Training in project design and requirements	Strengthening of DNA	Need for long term financing for unit

The issues of public awareness, vulnerability of the coastal zone, and development of a national action plan for climate change are the key areas which need to be addressed in terms of capacity building.

As Jamaica does not produce any fossil fuels and is totally dependent on imports, the cost of energy significantly impacts the economy. Through the technology needs assessment process, a number of key mitigation technologies were identified as priorities for Jamaica for the energy sector. These were:

- Natural gas technology for end-use consumption and transport;
- Diesel technology for new vehicles;
- Renewable energies, including wind, hydro, solar and photovoltaic.

See Section 5.2 for more information.

Jamaica like all SIDS will also require technologies for coastal zone adaptation. As noted in Section 5.2, technologies to protect from sea-level rise will be required. Sea defence structures may be applicable under certain circumstances. Soft technologies will also have many applications, such as the preservation and regeneration of mangroves and the more effective application of coastal zone management techniques. Improved data collection and the reinstatement of the tidal gauge network are also needed to aid in planning and project designs that reduce vulnerability.

Jamaica also considered the application of various adaptation technologies in the water sector to improve overall management of the water sector and to combat climate change, such as an improved hydrometric network; additional river gauges and automatic weather stations to aid in data collection; additional water-management software; and improved flood warning systems (see Section 5.2).

5.3.2 Public Education and Awareness

Although low public awareness and inadequate private sector support for climate change issues have been identified as critical issues in Jamaica, there are not enough funds allocated for public awareness and education. Any new project which the Jamaican government is involved in as it relates to climate change must have public education and awareness as a key component. There may also be the need for specialized staff to address the issue of climate change.

A climate change survey conducted as part of the ”top-up” project highlighted the general feeling of complacency and indifference towards climate change and its impacts. The perception of most respondents in the survey revealed that they viewed climate change as a change or variation in global climate accompanied by changes in temperature and weather patterns. It is clear that there is misunderstanding about climate change, its causes and its impacts. Electronic media was identified as the best way to improve awareness about climate change – a point also highlighted in the technology needs assessment workshops. Thus, any climate education programme must focus heavily on the use of the electronic media. This may involve the development of a partnership with a media house.

There will also need to be a stand-alone climate change public awareness programme which eventually will have to be incorporated into an overall environmental awareness programme. Targeting a climate change programme for the schools will not be difficult, as schools are usually very receptive to such issues. Essay competitions on climate change as well as the development of educational material can be distributed in schools, and will be effective. There could also be the development of a climate change jingle or song which could be the theme for all climate change activity

For the climate change education and awareness programme to be effective, there will also need to be synergies with other issues. For example, the linkage with disaster management should be exploited, particularly given the fact that Jamaica has been affected by a number of hurricanes. A joint strategy could be developed between the Meteorological Service and the Office of Disaster Preparedness and Emergency Management (ODPEM) with regards to climate change and disaster management. Linkages also need to be made with the energy sector for the development of joint programmes.

There could also be the development of short “climate points” which could be delivered in the broadcast media at the end of every weather forecast. These points could focus, for example, on the effect of a 1-metre sea-level rise or what the greenhouse effect is, or what the Jamaica’s GHG emissions are and what can be done to reduce them.

There will be also a need to sensitize the corporate sector as to the importance of climate change. A consultation with the corporate sector on climate change issues may be required. Corporate sponsorship could be sought for the development of these climate points.

The development of a short documentary on climate change should also take place. This could discuss the issue of climate change, highlight the vulnerable areas in Jamaica, adaptation options and required changes in behaviour, as well as focus on energy issues. Such a project should be a joint venture with the respective offices responsible for disaster management, water, energy, agriculture, and the Meteorological Service. Corporate sponsorship may have to be obtained to facilitate such a venture. Funding for public awareness may have to come from external sources. All climate change related projects, however, should include substantial funds for public awareness.

Conclusions and Recommendations

Public awareness and education is a key component for any climate change programme; however funding may be a constraint. Thus, in designing the Second National Communication, sufficient funds must be put aside for public awareness. There is a need for greater collaboration with agencies who have an interested with climate change to ensure an integrative approach to climate change, particularly as it relates to public awareness.

With vulnerability being a key issue, it is clear there is room for the development of a vulnerability project in Jamaica. There are two possible projects which could be put forward. The first relates to the vulnerability of the tourism sector and climate change. The north coast could be used as a pilot site, and social economic issues considered, given the amount of persons employed by the industry. The second project relates to the vulnerability of Kingston and surrounding areas to sea level rise. Thus issues related sea level rise, the harbour and airport can be addressed. The projects should include funds for public awareness and should be submitted to the GEF for funding.

5.4 Review of the Initial National Communication

The Meteorological Service administered the GEF-funded project to prepare Jamaica's Initial National Communication from October 1998 to the submission date in November 2000. A project steering committee consisted of representatives from various government departments. The University of the West Indies provided oversight and monitoring for implementation of the project. An assessment of the Initial National Communication follows.

National circumstances: Chapter 1 provides comprehensive data on the history of Jamaica, population growth, economic trends, and climatic data. The national circumstances table lacks information with regards to the population in absolute poverty; however information on the percentage of the population in poverty is located later in the chapter. This chapter is very comprehensive, and provides all the relevant information required under decision 10/CP.2.

GHG inventory: Using the IPCC 1996 Revised Guidelines for preparing GHG inventories, Jamaica selected 1994 as the base year for its inventory. Jamaica's emissions of carbon dioxide in 1994 were 8,585 Gg, methane, 58.47 Gg, and nitrous oxide, 344 Gg. While the inventory is considered quite accurate, there is query with regards to methane emissions in the agriculture sector. The methodological approach for calculating rice production emissions was applied to sugar cane production, given that 17,056 hectares of sugar cane was produced using an intermittent flooded system. However, the related scaling factors used in the calculations are for rice and not sugar cane. In addition, sugar cane is intermittently flooded, and not continuously flooded like rice. There are the some assumptions and approximations which have thus affected the accuracy of the calculation of the methane emissions. These assumptions and approximations need to be addressed.

Vulnerability and adaptation: Given the vulnerability of Jamaica as a small island developing state, an entire section of the national communication highlights this issue. The chapter gives an initial investigation of the effects of climate change on key sectors in Jamaica and highlights the vulnerability of the coastal zone, water and agriculture sectors to a changing climate. Initial adaptation options are identified. Many of the issues related the general steps which the country has taken to implement the Conventions are addressed.

Information and technology needs: The National Communication identifies the constraints which occurred during the preparation process, and provides recommendations for national actions, as well as identifying information gaps and technological needs, and project suggestions.

Jamaica fulfilled its requirements to the UNFCCC with regards to the Initial National Communication. In many instances, considerably more information was provided than is required by the guidelines for national communications as outlined in Decision 10/CP.2. Additional information could have been provided on the status of the renewable energy sector, while other vulnerable sectors such as the tourism and health were not considered comprehensively. Some project proposals with detailed budgets could have been annexed so that potential donors could provide funding for priority projects.

Design of the Second National Communication

Decision 17/CP8 contained new guidelines to be used for the preparation of second, and where appropriate third national communications. The guidelines are thus more detailed than those for the Initial National Communication and will require additional capacity. It was noted that the project manager for the Second National Communications for Jamaica should have had considerable experience in the Convention process, and in the preparation of the Initial National Communication.

Among the improvements and/or elements planned as a result of the analyses of the Initial National Communication were:

- Use of new recommended base year of 2000 for the GHG inventory;
- Inclusion of two other years, e.g., 2002 and 2004, so that trend analyses can be conducted, along with abatement planning and options and inclusion of programmes and measures to mitigate climate change;
- Training on GHG inventory preparation and examination of possibilities for institutionalizing the preparation of the GHG inventory;
- Further examination of issues related to climate change and disaster management for the coastal zone, water, and agricultural sectors;
- Analysis of the impacts of climate change on health and tourism, and the possible socio-economic impacts on society; and
- Incorporation of elements and outputs of the MACC project;
- Incorporation of concrete project proposals requiring funding.

These improvements were discussed during the national consultations and stock taking process that took place as part of the preparatory phase to design and plan the Second National Communication.

Chapter 5 References

National Meteorological Service (2000). Jamaica's First National Communication to the United Nations Framework Convention on Climate Change, Government of Jamaica. November 2000.

Ministry of Commerce. Science and Technology (2004). Draft Power/Electricity Policy for Jamaica. September 2004.

Appendix 1: Project Concept for Improvement of the Systematic Observation Systems of the Meteorological Service of the Government of Jamaica

Background: Through the Global Environmental Facility and the United Nations Development Programme, the Government of Jamaica received US$100,000 to further capacity building activities as they related to the Initial National Communication of the Government of Jamaica under the United Nations Framework Convention on Climate Change. One of the issues addressed was improvement of the current systematic observation systems of the Meteorological Service of the Government of Jamaica.

Currently, there are currently seven automatic weather stations deployed in Jamaica. The weather stations are located at: (i) Negril Point, Westmoreland, (ii) Montego Bay, St James, (iii) Norman Manley International Airport, Kingston, (iv) Morant Point, St Thomas, (v) Pedro Bank, (vi) Folly Point, Portland and (vii) Discovery Bay, St Ann's. Through the Caribbean Planning to Adaptation to Climate Change (CPACC) project, two automatic weather stations and tidal gauges were obtained. One was installed at Port Royal and the other at Discovery Bay. However, the seven weather stations are not enough to ensure that a comprehensive data base can be created with regards to the climate in Jamaica.

Project Rationale and Objectives: An improvement in the systematic observation system will improve the overall climate data base in Jamaica and allow Jamaica to: (i) more effectively participate in Global Climate Observation Systems, and (ii) "ground truth" data from Jamaica's Doppler RADAR. Additional automatic weather stations will assist in improving critical data which can then be utilized for a variety of purposes such as disaster management and agriculture. The outputs of the assessment on observation systems in Jamaica recommended that 13 automatic weather stations be added to the current complement. These proposed additional stations will allow for a more comprehensive coverage of Jamaica, with at least one automatic weather station in each parish. The proposed location of each automatic weather station is listed in Table 1. In addition to the installation of the stations, there would be the associated training, with regards to operation and maintenance of the automatic weather stations.

Expected Outcomes: With the addition of the new automatic weather stations the overall operation and functioning of the Meteorological Service will improve. The Meteorological Service will be able to more effectively obtain information with regards to the local weather conditions and improve the quality of climatic data. The additional weather stations will also improve the country's planning as it relates to a number of sectors of the economy

Budget: Automatic weather stations which are manufactured by Microcom Design Inc, Maryland, and USA have been identified as being suitable for Jamaica. These automatic weather stations can be connected by satellite so that data can be remotely connected and transmitted. The cost of one automatic weather station is US$10,703. Table 2 gives an estimated budget for installing the 13 weather stations, along with associated maintenance, shipping, and training costs.

Table 1: Proposed Locations of Additional Weather Stations

Location	Parish
Savannah-La-Mar	Westmoreland
Lucea	Hanover
Cambridge	St James
Black River	St Elizabeth
Balaclava	St Elizabeth
Alexandra	St Ann's
Oracabessa	St Mary
Annotto Bay	St Mary
Portland Ridge	Clarendon
Alligator Pond	St Elizabeth
Mandeville	Manchester
Worthy Park	St Catherine
Ocho Rios	St Ann's

Table 2: Estimated Budget

Item	Cost (US $)
13 Microcom Automatic Weather Stations	139,139
Spares (3 Towers and 3 Static Dissipaters)	3,582
Shipping and Documentation	3,120
Installation and Training	5,000
Total	**150,841**

CHAPTER 6: CONSTRAINTS AND GAPS, AND RELATED FINANCIAL, TECHNICAL AND CAPACITY BUILDING NEEDS

Capacity and technical constraints related to the National Communications Process, along with barriers to technology transfer, are discussed in detail in Chapter 5. Chapter 5 (Appendix 1) also includes a project concept for the improvement of the systematic observation systems of the Meteorological Service of Jamaica.

The remainder of this chapter is devoted to proposed improvements to the GHG inventory process planned as part of the Third or future National Communications.

6.1 Data Gaps and Suggested Improvements to the National GHG Inventory

Energy Sector

- Compile fuel use and other activity data (production) by at least four digit ISIC codes. Where quantities are small and not readily or cost effectively compiled or disaggregated, the data collection should be geared to providing aggregates based on ISIC codes. The current compilation of fuel consumption data is based on sectors (which can be identified with ISIC codes) and geography (namely, rural and urban) which cannot be identified with economic activity (ISIC codes).

- Data collection should be improved in order to allow better distinctions of diesel fuel use to be made between on-road and off road transportation activities and other fuel combustion activities by sector.

- Fuel consumption data for some mining activities (bauxite mining by third party companies) and for lime production should be captured.

- Fuel consumption for aircraft registered in Jamaica should continue to be compiled. This will be even more critical after closure of one of the domestic aerodromes and its relation to the Norman Manley International Airport.

- Production data for lime production should be reported for all manufacturing facilities.

- The vehicle fleet data base contains many serious discrepancies which should be corrected over time by implementing quality assurance and quality control procedures to avoid data entry errors (weights, vehicle age, manufacturers etc.) and minimize other errors (fuel type, VIN numbers).

Industrial Processes and Product Use Sector

- Although the uncertainty in emissions from cement manufacture is low, some enhancement could be made by using chemical analyses for clinker produced.

- Import data for HFCs did not always identify all items in shipments. Because of the wide variation and relatively high global warming potentials for HFCs, such identification is essential for obtaining more reliable estimates.

- HFCs have been and are being used in fire suppression systems but data on the systems in place are lacking.

- Paint production data that are compiled and reported and paint specifications do not allow the key environmental issue regarding paints to be addressed. The current specifications include volatile matter which includes water – instead of isolating volatile organic compounds. Revision of the standards based on paint types such as those used in North America or Europe (but adapted to Jamaica's market) is recommended.

Agriculture, Forestry and Other Land Use Sector

- The assignments of land use and changes in land use categories are based on outdated satellite imagery. Updated satellite imagery data complemented by suitable ground based surveys and permanent sample plots to measure growth rates are needed in order to improve the quality of the land use change data and to develop country-specific growth rates. This information will significantly improve the accuracy of the inventories as well as inform land-use policies and forestry management.

- Agricultural census data are compiled approximately every 10 years and mechanisms should be established to allow estimates in the intervening years for those data that are important but not currently compiled. These include data for goats and sheep as well as manure management practices for all animals and the amounts of crop residues remaining in the fields.

- Information on the wood conversion (i.e., removals for various purposes such as fuel wood, timber, and agriculture) on privately owned lands is lacking. The design of suitable, viable solutions to obtain such data is challenging but options that should be considered include legislation and well designed, periodic surveys.

Waste Sector

- Reliable data on the loading (volume and BOD or COD) of releases from sewage treatment and industrial wastewater plants are lacking. The enactment and enforcement of Wastewater and Sludge Regulations being drafted by NEPA should remedy this situation. For instance, flow meters could be required at sewage treatment facilities and/or facilities required to regularly submit information.

- Reliable data for the types and quantities of industrial waste generated and disposed of in municipal and industrial waste disposal sites are lacking.

- Some data for municipal waste are now being compiled by the NSWMA, but ongoing and additional determination and estimates of waste stream disposal methods (collected, uncollected, treatment methods including open burning) will assist in making more reliable inventory estimates as well as inform waste reduction and other waste management strategies.

- Enactment of Pollutant Release and Transfer Regulations will assist in providing data for air emissions, trade effluent and solid waste releases and transfers and transfers and also provide a mechanism for ongoing compilation and archiving of these data.

- Additional information on population according to income groups and the degree of utilization of sewage treatment systems (sewered, not sewered, pit latrines) by parish and urban and rural areas is needed. STATIN and PIOJ need to collect and present data in the same format annually.

- Data on the quantities and disposal and treatment methods of clinical and industrial solid wastes are lacking. The Air Quality Regulations (2006) under the NRCA Act should improve some of the data availability (e.g., when waste is incinerated) for future inventories.

- While challenging, NEPA needs to ensure that small facilities which do not fall within the licensing system of the Air Quality Regulations (2006) use the best available technology and /or best practices to operate their facilities.

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