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IDENTIFYING INCONSISTENCIES IN LONG-RUN DEVELOPMENT PLANS: THE CASE OF BARBADOS' VISION FOR ENERGY DEVELOPMENT

BY

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CENTRAL BANK OF BARBADOS

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Abstract

Barbados spends approximately seven percent of annual gross domestic product (GDP) on imported fuel, a significant amount in a foreign exchange constrained economy. In addition, to the foreign exchange burden of imported fuel, the relatively high cost of electricity is a major constraint impacting on the external competitiveness of local businesses. This paper uses a model of long-run energy development for Barbados to evaluate whether there are gaps in the medium to long-run vision for energy development in Barbados. It is expected that the study would be able to identify any potential shortfalls in future energy supply under various scenarios of economic development.

Keywords: Energy development; renewable energy; sustainable development
JEL codes: Q4; O54; C6

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1 Introduction

While Barbados has a relatively high standard of living, the island is still characterised by many of the same vulnerabilities affecting most small island developing states. In 2012, Gross National Income (GNI) per capita (PPP current international $) was $15,574, approximately 7 percent above the average for Latin America and the Caribbean but less than half the income average of Organisation for Economic Cooperation and Development (OECD) states. In 2013, the island's Human Development Index score was 0.776, or 59th out of the 187 countries assessed in the report and falling into the high human development category (United Nations Development Programme, 2014).

In contrast to these achievements in relation to economic and human development, however, the island is still very dependent on imported fossil fuels to meet most of its energy needs. Castalia (2010) estimates that domestic production accounts for just 15 percent of total energy needs. This dependence on imported fossil fuels implies that the demand for energy is price inelastic, i.e. demand is relatively unresponsive to price shocks(Moore, 2011). The island, therefore, is highly susceptible to shocks to international oil prices (Lorde, Waithe, & Francis, 2010), given the dependence on imported fossil fuels. At the household level, however, Carter et al. (2012) notes that the price elasticity of demand for electricity tends to vary with the appliances that each household utilises, with households that utilise energy saving devices (e.g. solar water heaters) being more price elastic.

Barbados has had a long history with renewable energy. By as early as 1995, driven in part by high energy prices and generous tax incentives the island had installed solar water heaters on more than one third of all households (Headley, 1997). Prior to this, sugarcane – previously the main export of the island – was ground using windmills for some 300 years and then in recent years the biomass from its sugar production used to power the factory. Energy consumption, therefore, has always been a key input into the growth and development process of the island. Indeed, Lorde et al. (2010) report that there exists a bidirectional causal relationship between electrical energy consumption and real GDP in the long run. Given this relationship between growth and the demand for energy Francis et al. (2007) therefore recommend that Barbados, along with other Caribbean countries, need a greater long-term commitment to implement policy, economic, market and research development measures in order to enhance the utilisation of alternative energy sources.

In 2009, the Government of Barbados obtained technical assistance from the Inter-American Development Bank to develop a Sustainable Energy Framework for the island. The main of objectives of this framework was to promote greater use of renewable energy and encourage energy efficiency (Castalia Ltd, 2010). This framework document made a number of recommendations in relation to enhancing the use of renewables and encourages energy efficiency in Barbados. In relation to renewable energy it was proposed that the follow energy systems be incorporated onto the grid: utility scale wind farm (40MW), biomass cogeneration (20MW), solid waste to energy (13.5MW), solar water heating (19.7MW) and solar PV (20MW). In relation to the energy efficiency recommendations it was recommended that there should be a greater utilisation of efficient lighting, air conditioners, premium motors, chillers, variable frequency drives and power monitors. These renewable energy and energy efficiency recommendations were expected to reduce electricity costs, reduce CO_2 emissions and reduce the island's dependence on fossil fuels by 71 percent.

The sustainable energy framework outlined for the island in Castalia (2010) contains recommendations that could significantly reduce the vulnerabilities of the island, but does not consider how these recommendations fit into the overall economic development of the island. If one ignores the economic developments taking place on the demand-side this could lead to either an over-provision or under-provision of energy. In addition, these economic developments could produce savings, through multiplier effects, that cannot be captured in a simple benefit cost analysis exercise. This paper therefore contributes to the literature building a disaggregated model of the island's long run energy development that accounts for both supply-side energy features as well as demand-side changes, particularly in relation to energy efficiency. It is expected that the modelling framework developed can be of use for policymakers in Barbados, and could serve as a framework for future work in other small island developing states.

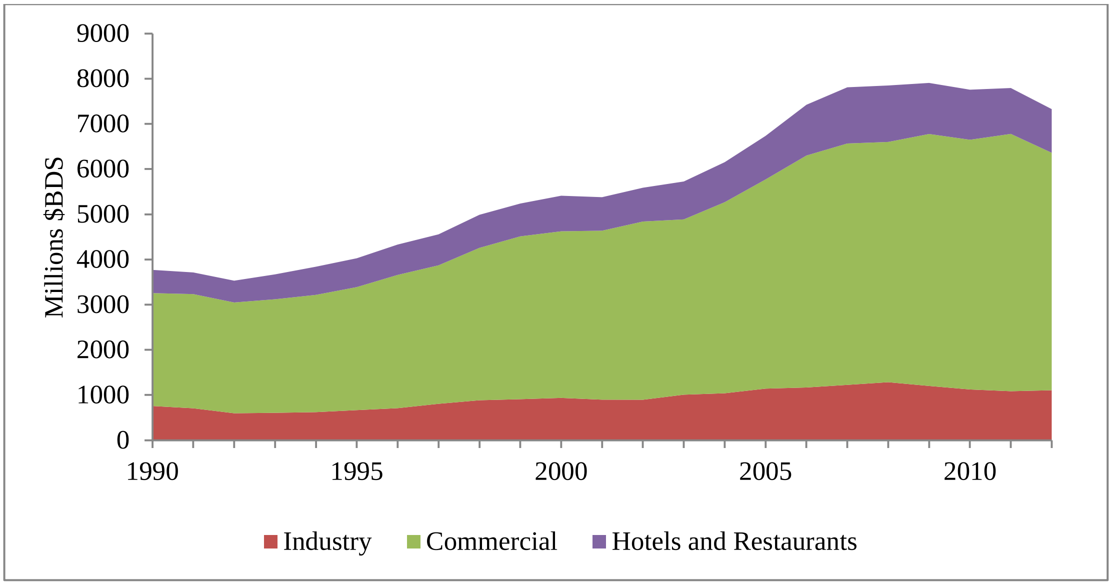
The remainder of the paper is structured as follows. Following the introduction, Section 2 provides a summary of the institutional and regulatory background of the island. Section 3 gives details on the long run model of energy development employed in the study to assess the island's sustainable energy framework. Section 4 outlines the main findings, while Section 5 concludes and provides a discussion of the results.

2 Background

This section of the paper provides a brief overview of Barbados and how energy fits into the islands development profile. Barbados is an island within a regional cluster known as the Lesser Antilles. It has a land area is 431km^2, 34 km from north to south and 23 km from east to west or just over one-third the land mass of Hong Kong. With a population of 277,812, the island is one of the most densely populated in the region.

Economic activity in Barbados has almost doubled over the last two decades, driven largely by the growth in tourism and commercial activity. In 1990, total value-added generated by domestic industries was estimated at BDS$4 billion. By 2007, the estimated size of the economy was just under BDS$8 billion, but has fallen since then due to the effects of the Great Recession. Commercial (service) represent the single largest group of economic activities, with more than $0.70 out of every dollar of GDP due to this group and is largely made of up of finance, distribution and public sector activities.

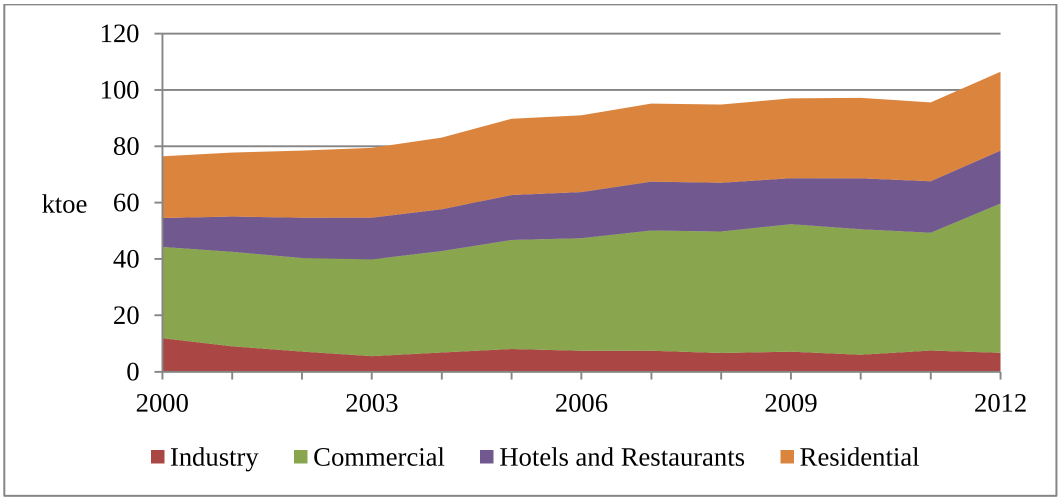
Figure 1: Evolution of Gross Domestic Product (Current Year Prices) in Barbados



Source: Barbados Statistical Service

Sectoral energy use in the island basically matches the structure of the domestic economy. Since 2000, final energy use has risen from 76 ktoe to 106 ktoe by 2013, an average annual increase of 2.3 or 3 percent. Commercial industries account for the largest share of final energy use, with almost half of all energy consumed in the island. Following the commercial industries, households (27 percent) and hotels and restaurants (18 percent) account for the bulk of the remainder of final energy use on the island.

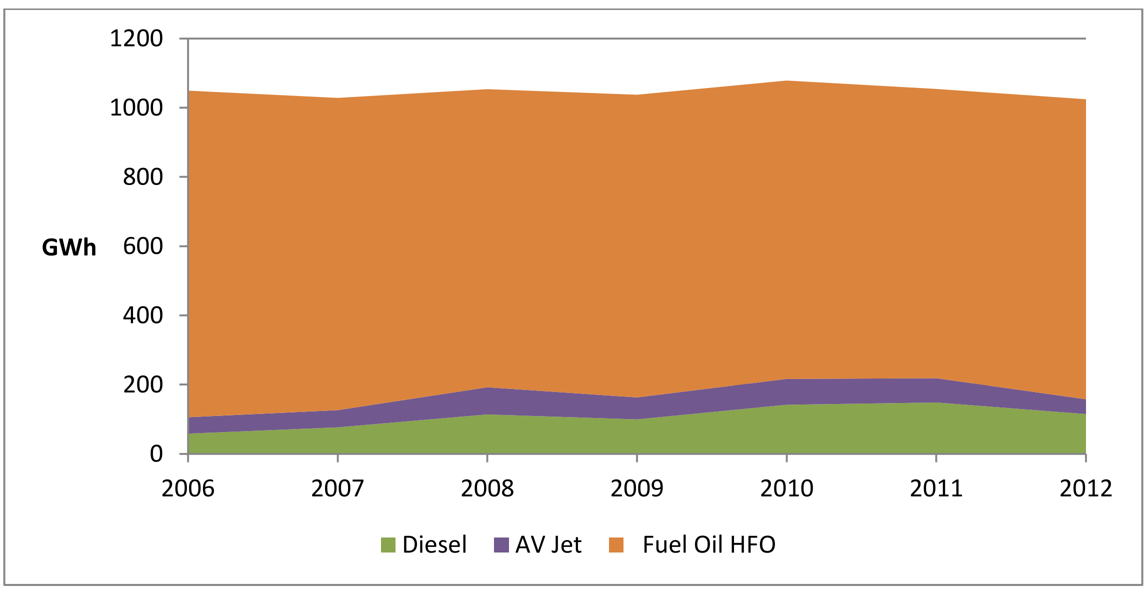
Figure 2: Sectoral Final Energy Use in Barbados



Source: Division of Energy and Telecommunications, Barbados

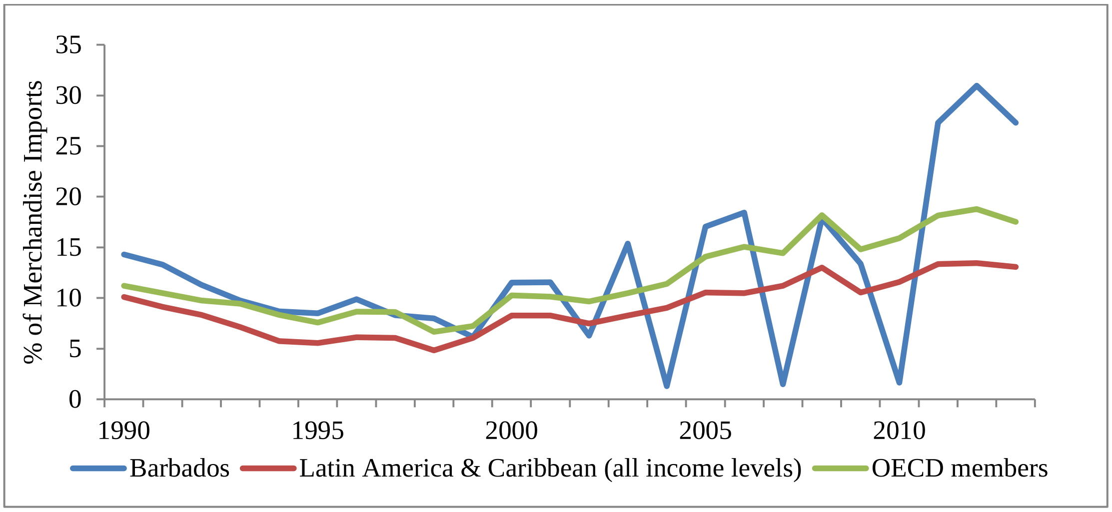
Most of the island's primary energy demands are met through the use of imported fossil fuels. This dependence on international fossil fuels, however, makes the island highly vulnerable to changes that take place on the international market. On average the fuel import bill has accounted for 10 percent of total import imports and approximately 5 percent of GDP over the last ten years. Imported fossil fuels also account for most of the country's energy, including the generation of electricity (Figure 3). In recent years, the island's dependence on imports has climbed substantially, mirroring the rise in oil prices, to almost 30 percent between 2010 and 2014 (Figure 4). Indeed, Barbados' dependence on imported fossil fuels is, on average, above that for the average country in Latin America and the Caribbean and the group of rich Organization for Economic Co-operation Development (OECD) states. Besides the burden placed on foreign exchange reserves, high fuel prices when translated into high energy cost impact on the external competitiveness of local businesses and the overall cost of living(Compete Caribbean, 2014).

Figure 3: Electricity Output in Barbados by Energy Source



Source: Division of Energy and Telecommunications, Barbados

Figure 4: Fuel Imports in Barbados and Selected Country Groupings



Source: World Bank's World Development Indicators (Online)

Energy policy falls under the remit of the Division of Energy and Telecommunications in the Prime Minister's Office. The Division monitors and regulates the energy industry as well as promotes the use of renewable energies and energy-efficient technologies. The Division is responsible for the broad energy policies of the island, but the Barbados National Oil Company (BNOC), the Barbados National Terminal Company Limited (BNTCL) and the Barbados National Petroleum Corporation (BNPC) manage day-to-day issues related to production, distribution and imports. BNOC is responsible for exploration, production and procurement of oil and gas onshore. BNTCL, on the other hand, imports and stores all oil as well as crude oil products. Finally, the BNPC distributes the gas produced by BNOC.

Beyond the primary energy supply, the Barbados Light and Power is the sole producer of electricity and has been in existence since 1909, following the passage of the Electric Light and Power Act by the Barbados House of Assembly in 1899 and its enactment in 1907. Although diesel is the primary fossil fuel used to generate electricity (Figure 3), there has been some introduction of photovoltaic systems to the grid and there has been commitment to the pursuit of a co-generation plant since the turn of the century. In addition, proposals have been made with respect to the possibility of incorporating wind energy into the grid.

These and other proposals are representative of the societal shift towards renewable energy sources and greater energy independence(Castalia Ltd, 2010).

The regulatory framework governing electricity is covered by four major pieces of regulations in Barbados (Table 1). Regulatory issues in relation to pricing and interconnection are covered under the Fair Trading Commission while the Electricity Act governs issues in relation to the inspection and control of electricity on the island. The most recent piece of legislation, the Electric Light and Power Act, sets regulations in relation to supply and use of electricity from the public grid, interconnection, targets for renewable energy, and issues in relation to the security and reliability of electricity supply.

Table 1: Laws and Regulations Governing the Electricity Industry in Barbados

Legislation	Provisions	Implementing Agency
The Electricity Act (1899)	Provides for the inspection and control of electric works by the Electrical Engineer.	Electrical Engineering Department
The Electric Light and Power Act (2013)	Facilitates and regulate the supply and use of electricity for lighting and other purposes.	Fair Trading Commission
The Fair Trading Commission Act (2001)	Provides for the establishment of a Fair Trading Commission to enforce the Utilities Regulation Act and any laws relating to consumer protection and fair competition.	Fair Trading Commission
The Utilities Regulation Act (2001)	Provides for the regulation of utility services including setting principles for rate determination, the setting of maximum rates and determining the standards of service.	Fair Trading Commission

Source: (Castalia Ltd, 2010)

Given the island's dependence on fossil fuels and the impact this has on economic development, policymakers in recent years have started to target issues related to renewable energy and energy efficiency. The country's National Strategic Plan (GOB, 2005) identifies six strategic goals: (1) cultural transformation; (2) governance; (3) people; (4) environmental preservation; (5) competitiveness; and, (6) branding. Under the pillar related to environmental preservation it was envisioned that the island would develop an "efficient and reliable energy sector". Specific strategies identified included the development of programmes to enhance the supply of renewable energy, diversifying the energy mix, expanding the use of natural gas through imported natural gas, exploring the use of solar and natural gas in transportation, energy efficiency and labelling standards as well as a programme to promote energy conservation. A number of targets were put forward as part of this vision:

1. 40 percent of energy from renewable sources by 2025;
2. 1,300 barrels of oil per day and 2 million cubic feet of natural gas from domestic sources;
3. 50 percent increase in households using solar energy for water heating; and,
4. 30 MW of electricity from bagasse cogeneration.

While these targets are consistent with the goal of greater energy independence they were developed without consideration of issues related to reliability and cost. Subsequently, a Sustainable Energy Framework for the island was prepared to contribute to the energy and environmental sustainability of the island(Castalia Ltd, 2010). The main objectives of the document were to lower energy costs, improve energy security and improve environmental sustainability. Taking account of the economic feasibility of the various technologies as well as their reliability, the Sustainable Energy Framework put forward the following goals:

- 29 percent of electricity consumption from renewable energy sources; and,
- 22 percent reduction in electricity consumption through the adoption of energy efficient technologies.

Economically viable renewable energy technologies include wind at a utility scale (on-shore and off-shore), biomass cogeneration, small-scale photovoltaic systems and municipal solid waste to energy. In terms of energy saving/energy efficient technologies these included compact fluorescent lamps, power monitors, magnetic induction street lighting, premium efficiency motors, efficient window air conditioning systems, variable frequency drives, efficient split air conditioning systems, efficient chillers and T5 high output fluorescent lamps and liquid crystal display computer monitors. It is expected that with sufficient take-up of these technologies electricity demand could fall by 24 percent, 22 percent, 12 percent and 48 percent in residential, tourism and commercial, industrial and public sectors, and street lighting, respectively. These renewable energy and energy technologies would lead to some degree of energy independence and also reduce the cost of electricity.

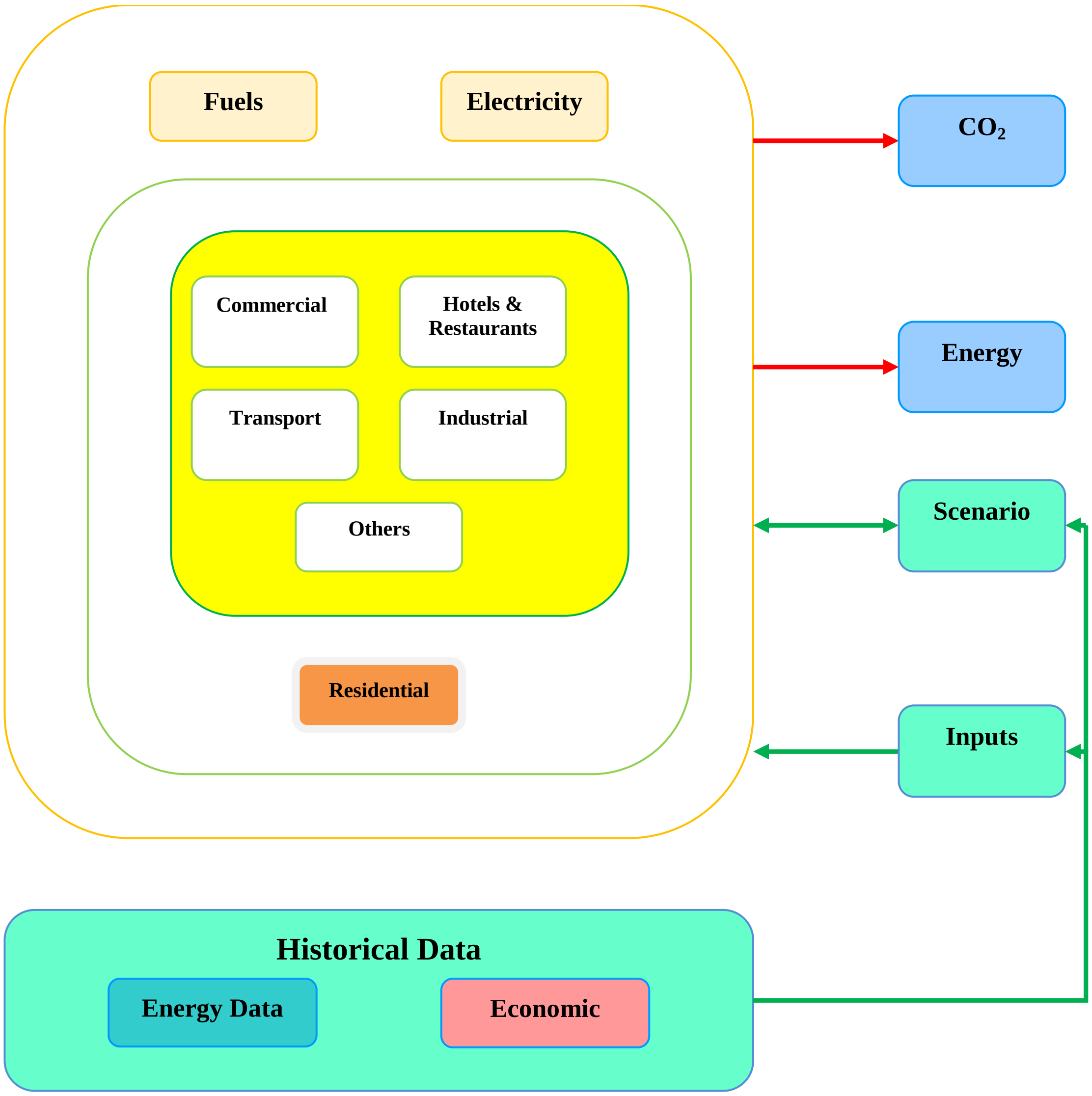
3 Empirical Methodology

Modelling the sustainability of any long-range energy plan is a complex undertaking, especially given the dynamic nature of many of the factors in the industry. For instance, the adequacy of a nation's medium-to-long energy framework can be greatly influenced by changes in social and economic variables, such as population, growth and technological advances(Urban, Benders, & Moll, 2007; Adams & Shachmurove, 2008; Lozano & Gutierrez, 2008). To properly assess the sustainability of a country's long run energy development, while giving due consideration to the dynamics introduced by such forces, the methodology used should allow for the optimisation of a user's time. This can be accomplished by having a flexible framework that facilitates the consideration of as many dynamic variables as reasonably possible.

This paper employs the Long Run Development Analysis (LINDA) energy model similar to that employed in Luukkanen et al. (2014), adapted to the case of Barbados in order to evaluate the island’s sustainable energy framework. The spreadsheet-based model is designed to construct future scenarios for energy use in various industries based on historical data with respect to variables such as Gross Domestic Product, Total Primary Energy Supply and the Energy Transformation process, as well as, user inputs such as data on projected sectoral economic growth levels and future changes in energy intensity.

The model's accounting framework (Figure 5), is built upon a network of interconnected pre-constructed calculations that enable users to track outputs such as carbon emissions by energy source, changes in a country's energy plant mix, projected changes in sectoral energy use and the interactions between supply and demand curves. The data used in the population of the model was compiled from a myriad of different sources due to the absence of any comprehensive or complete databases with respect to Barbados' energy industry. All energy-related data was first converted into their kilo tonnes of oil equivalent measurement unit before being entered into the model, while all other subsequent conversions occur within the system.

Figure 5: Barbados Linda Model Process Chart



With respect to the source of economic data, revised Gross Domestic Product (GDP) at current prices was obtained from the Central Bank of Barbados Online Statistics database for the period 1990-2012. These industries were then grouped in accordance with the range energy data was available for by sector. For instance, there is an absence of energy data related to agriculture, resulting its amalgamation into the commercial industry due to its close relationship with the wholesale and retail trade.

The decision to populate the model with the disaggregated form of GDP was also largely influenced by the desire to preserve the flexibility of the model. In this instance, the historical and economic significance of the tourism industry, as well as the availability of energy data for the hotel industry, lead to the decision to disaggregate this area of activity from the commercial grouping.

Information with respect to the indigenous production of natural gas and crude oil between 2004 and 2014 as well as the importation of gasoline, diesel and fuel oil for the period 2006-2012 were obtained from the Energy Division, Ministry of Finance and Economic Affairs. Fuel requirements for the generation of electricity, which encompassed the consumption of AV Jet Fuel, Diesel, Heavy Fuel Oils (HFO) and Natural Gas, along with the electrical outputs of various plant types including Gas Turbine, Low Speed Diesel plants and Steam Plants for the period 2006-2014 were also obtained from the Energy Division.

Information for the transport sector was amassed through several means. First, the consumption of gasoline and diesel for 2000-2013 sourced through the employment of the UN Statistic Division Energy Statistics Database, 2013, while estimates for statistics such as passenger numbers and goods transported were derived from OECD averages. Consumption data for both natural gas and electricity were obtained through the use of various issues of Barbados Economic and Social Reports, resulting in a database ranging from 2000-2012.

The paper utilises the model described above to compare and contrast five main policy scenarios to evaluate the likely implications for the energy supply mix in the island, energy demand, CO2 emissions and fuel imports from 2013 to 2040. From this analysis, the paper would be able to provide some assessment of the policy scenarios identified in the various policy documents and provide some recommendations for adopting, amending or abandoning these policy goals.

Table 2: Key Assumptions Used in Various Scenarios

Scenario	GDP (% change)	Electrical intensity (% change)	Transport volume (% change)	Road transport energy intensity (% change)	Energy intensity (%) change)
BAU	3%	-1%	4%	-2%	1%
Scenario 1 (National Strategic Plan)	5%	-2%	4%	2%	3%
Scenario 2 (Sustainable Energy Framework)	3%	-5%	4%	-2%	-5%
Scenario 3 (Growth and Development Strategy)	4%	-1%	4%	-2%	1%

All scenarios are compared relative to the business as usual scenario, which assumes that growth in economic output, consumption of energy, as well as production of energy are all in line with historical trends (

Table 2). This baseline scenario provides a benchmark and considers the case of no adjustment either in relation to the energy supply mix or consumption patterns. When a particular plant becomes obsolete, it is simply replaced with similar equipment that utilises the same primary energy source.

The first policy scenario is based on the 2005-2025 National Strategic Plan and contains fairly comprehensive targets for both fossil fuels and renewable energy technologies(GOB, 2005). These include 40 percent of energy from renewable sources by 2025, increased domestic production of oil to 1300 barrels of oil per day and 2 million cubic feet of natural gas per day, 50 percent increase in households using solar energy for water heating and 30 MW of electricity provided by bagasse cogeneration. The document also targets an average annual growth rate of 5 percent per annum.

The Sustainable Energy Framework (Castalia Ltd, 2010) developed for the island is less comprehensive in scope relatively to the National Strategic Plan (GOB, 2005), but the document still provides some indicative goals and targets for energy in Barbados. These targets include the generation of 29 percent of electricity from renewable energy sources, 22 percent reduction in electricity consumption (due to a 24 percent fall in residential, 22 percent in tourism and commercial as well as a 12 percent decline in industrial and public sector demand).

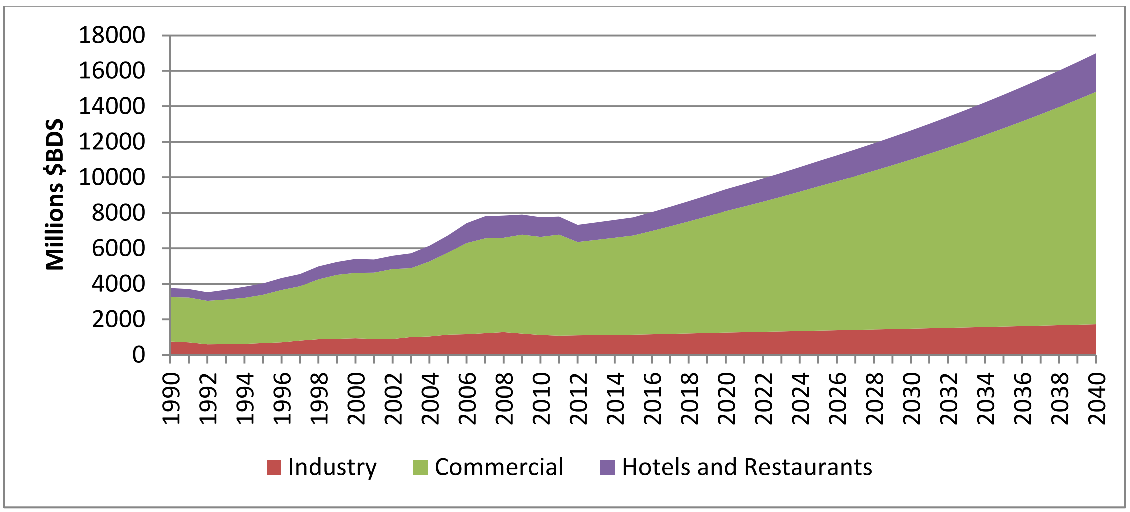
Given the effects of the global economic downturn on the Barbados economy, the Economic Affairs Division of the Ministry of Finance has also released a Growth and Development Strategy Document for the planning horizon 2013-2020(GOB, 2012). The document targets a medium-term growth rate of 4 percent per annum and an average annual rate of inflation of 3 percent. The document was, however, less specific in relation to renewable energy targets. However, it was noted that government should enable the development of a solar and bio-fuels industry, public education to enhance energy conservation, as well as incentives to develop the various technologies.

4 Empirical Results

4.1 Baseline Scenario

Based on the assumptions provided earlier, the baseline projections from the LINDA model provide the likely dynamics for energy consumption and economic activity in the Barbados economy. Figure 6 suggests that GDP in the island is likely to double over the 25-year period under review to reach just over $17 billion by 2040. This growth is forecasted to be driven largely by the commercial industry, which would expand its contribution to GDP from below 70% of GDP to just under 80% of GDP, as the share of GDP attributable to hotels and restaurants as well as industry declines(Craigwell, 2007). This deterioration is largely due to the deteriorating competitiveness of the economy due to its dependence on imported fossil fuels.

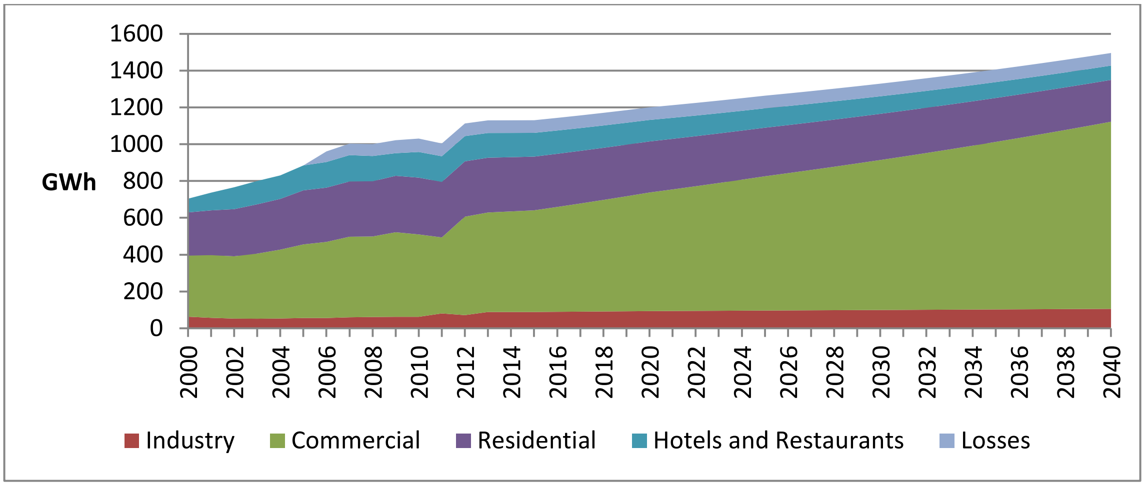
Figure 6: Projected Sectoral Economic Growth of the Business as Usual Scenario



Source: Model projections

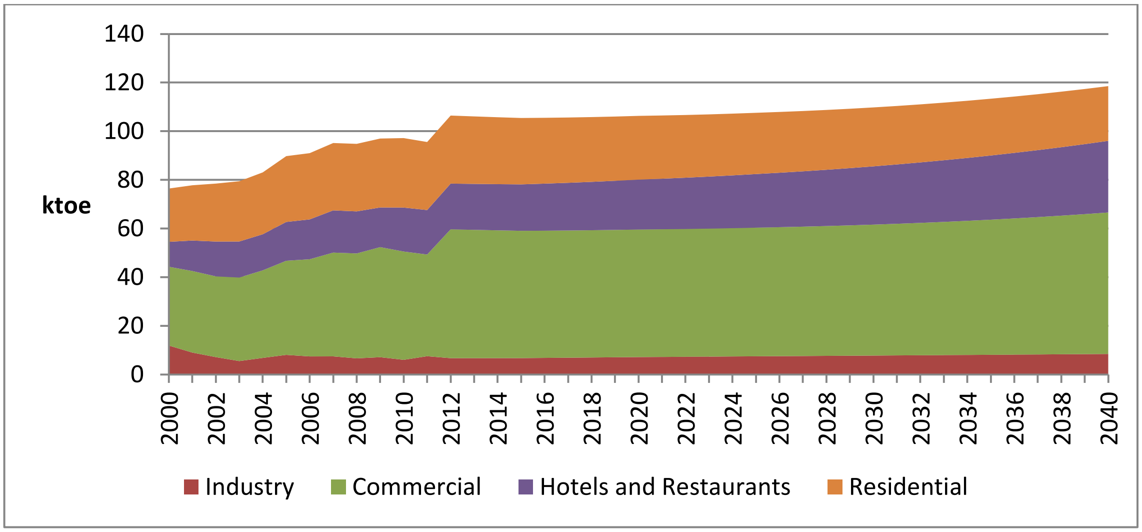
Given these economic trends, electricity consumption should be driven largely by the commercial industry. An estimated 1400 GWh would be needed by 2040 to meet the local demand for energy. Most of this demand would come from the commercial and residential segments. However, some reduction in the demand for energy is anticipated in the residential as well as the hotels and restaurants segments owing to efficiency and cost saving measures that would likely be adopted due to projected rising energy prices (Carter, Craigwell, & Moore, 2012). Similar trends for overall energy use are provided in Figure 8.

Figure 7: Electricity Consumption by Sector under BAU Assumptions



Source: Model projections

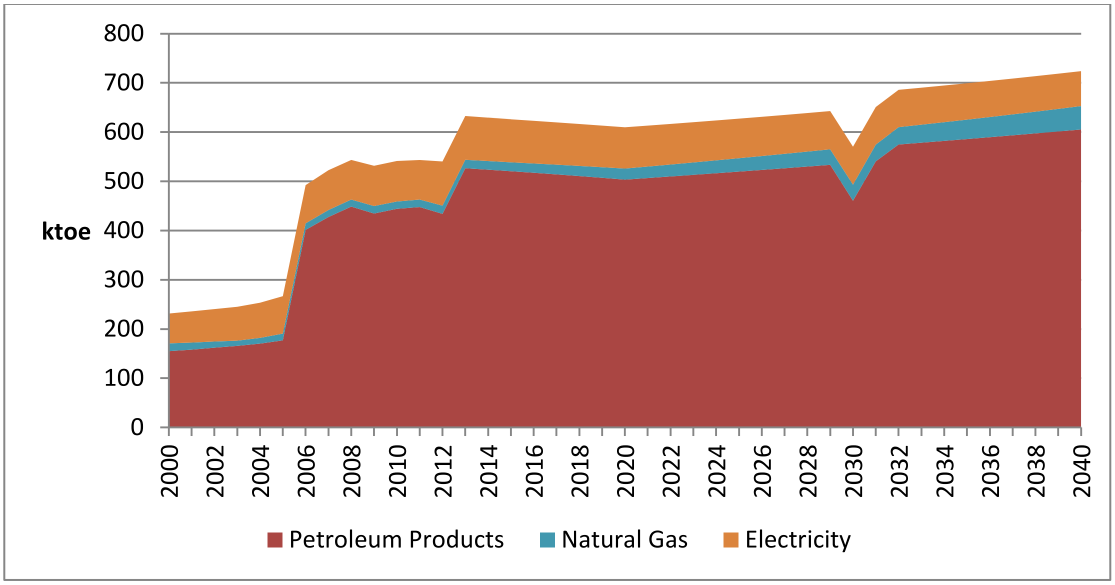
Figure 8: Final Energy Use by Sector under BAU Scenario Assumptions



Source: Model projections

On the supply side, the BAU scenario also assumes that most of this demand for energy would be met via a continued dependence on imported fossil fuels (Figure 9). While natural gas remains a cheaper option for electricity generation(Castalia Ltd, 2010), the falling supply of locally available natural gas might limit the possibilities for the expanded use of this energy source in the future(Castalia Ltd, 2014). By 2040, the demand for energy in the island would be 724 ktoe, almost three times higher than in 2000.

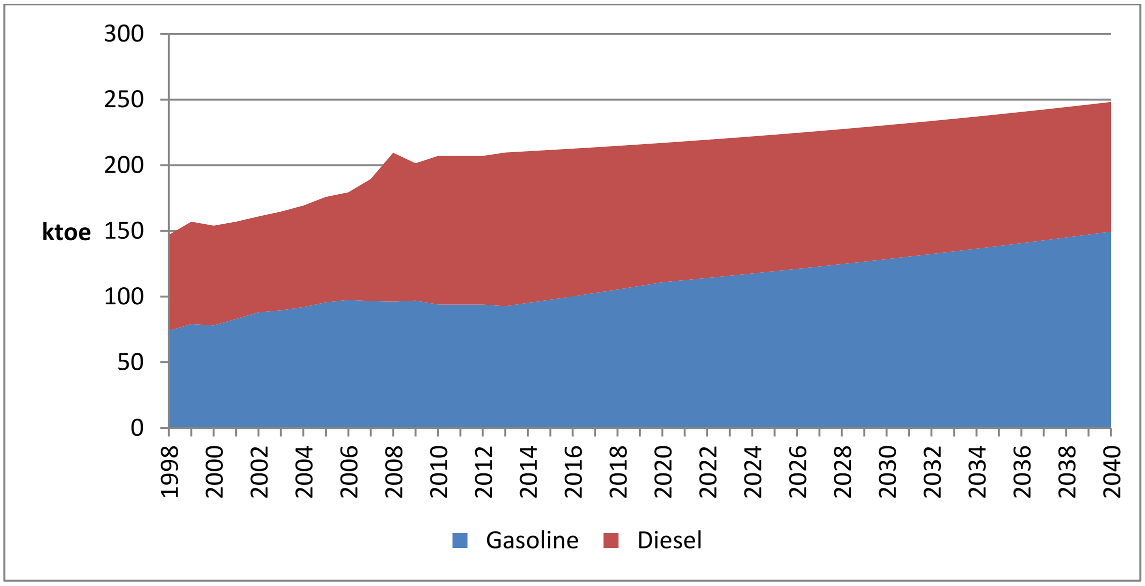
Figure 9: Fuel Consumption by Fuel Type under BAU Scenarios



Source: Model projections

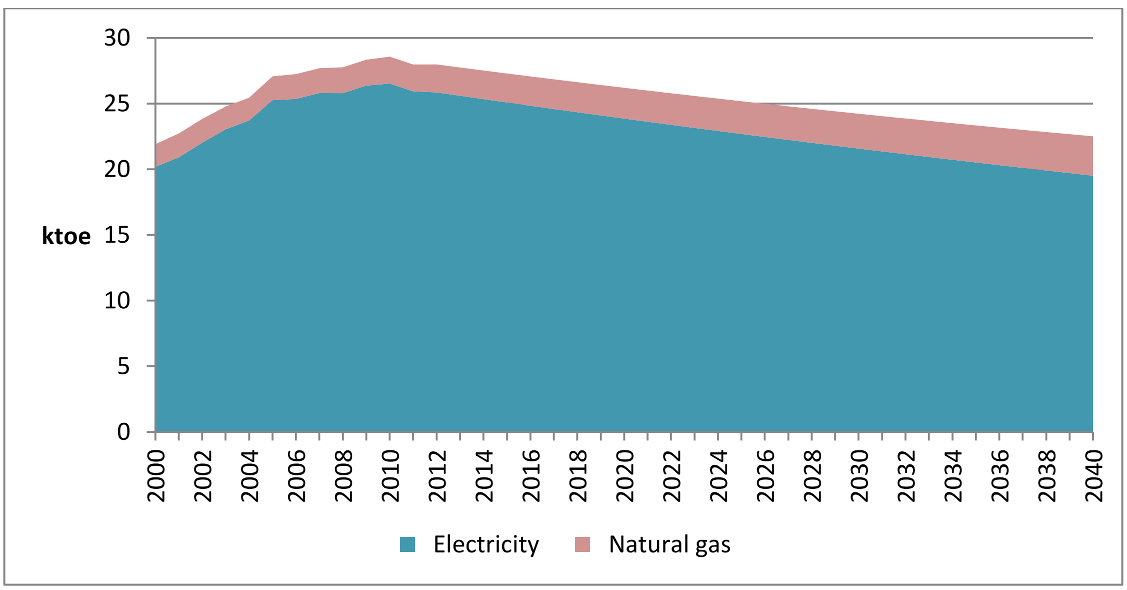
In terms of the type of fossil fuel used, the transport industry (Figure 10) – one of the largest consumers of energy – is anticipated to increase its demand for energy from 200 ktoe (mainly gasoline) to 250 ktoe by 2040. Similar increases in energy demand for the commercial as well as hotel and restaurant industries, are mainly met through supplies of electricity and natural gas, respectively. The only industry expected to experience a reduction in energy use is the residential segment of the market owning to greater efficiencies at the household level (Figure 11).

Figure 10: Transport Sector Fuel Use In Barbados given BAU Assumptions



Source: Model projections

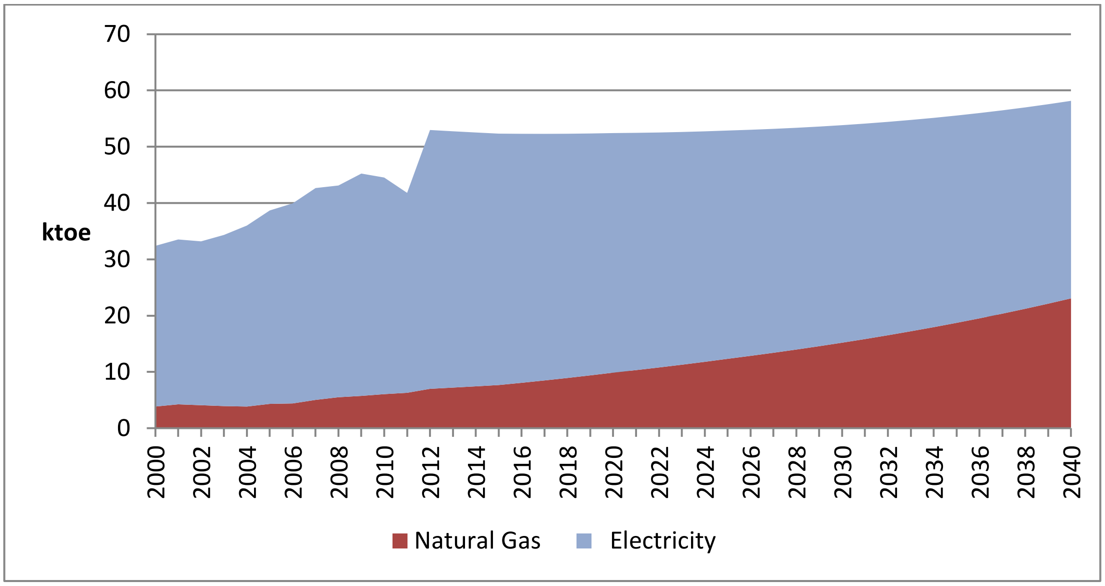
Figure 11: Residential Energy Use in Barbados given BAU Outlook



Source: Model projections

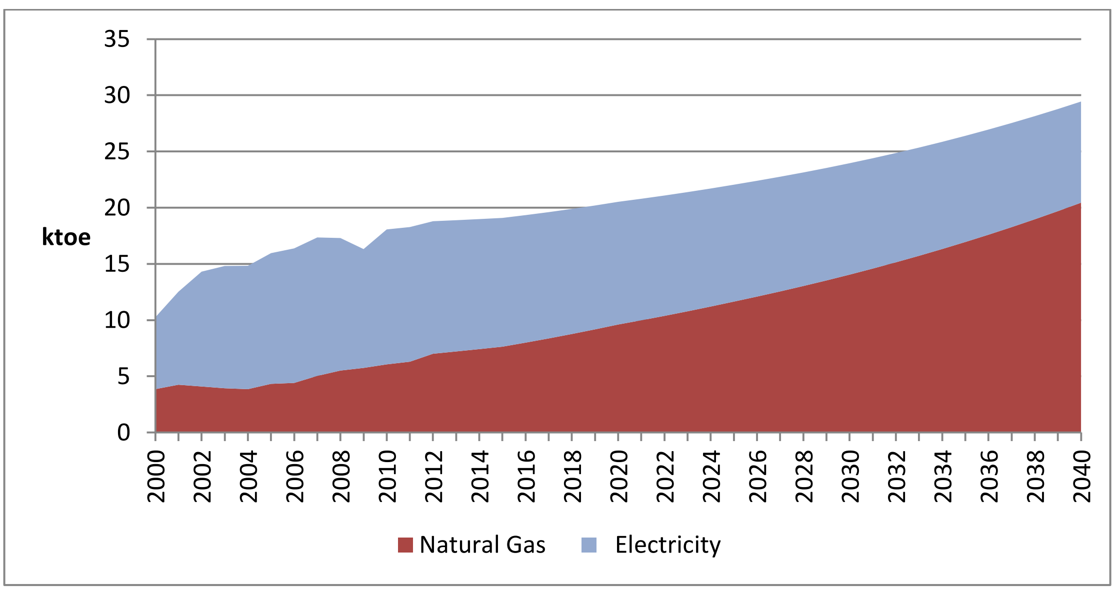
The reduction in residential energy use, however, will be more than offset by rising energy demand from the commercial (Figure 12) as well as hotel and restaurant industry (Figure 13). Based on present trends, most of the increase in the energy demand is anticipated to come from the commercial sector is likely to emanate from the natural gas industry. A similar pattern of growth is anticipated for the hotel and restaurant, as companies increasingly utilise natural gas as an input into production owing to its comparative cost advantages (Castalia Ltd, 2010).

Figure 12: Commercial Sector Energy Use in Barbados under the BAU Scenario



Source: Model projections

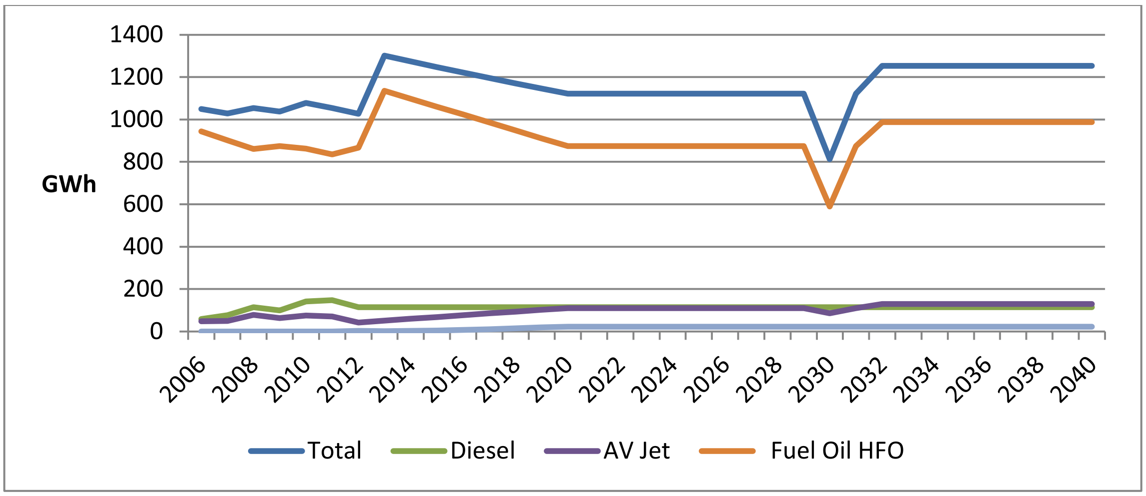
Figure 13: Hotels and Restaurants Energy Use in Barbados under the BAU Scenario



Source: Model projections

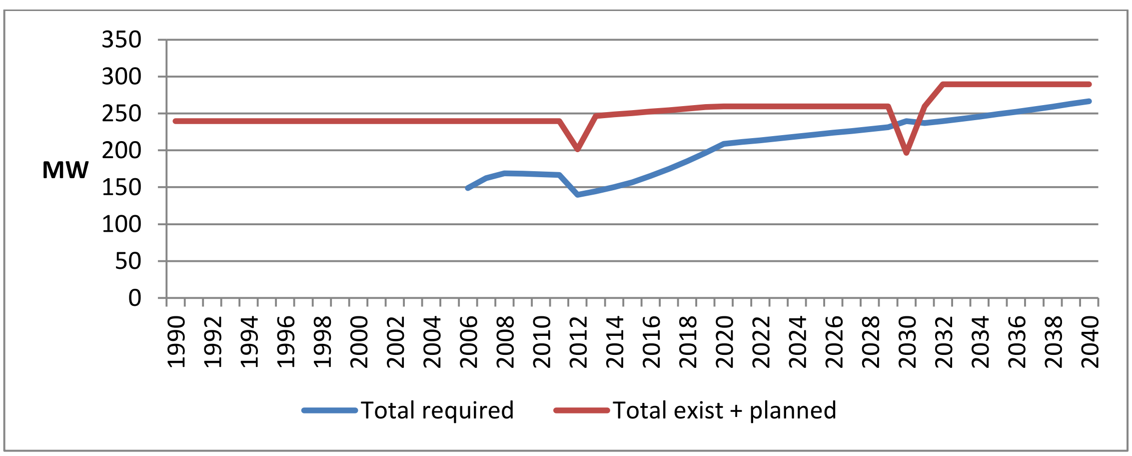
Assuming that the national provider of electricity maintains its current dependence on imported fossil fuels, primarily heavy fuel oil, then the capacity of heavy fuel oil plants is likely to be around 1000 GWh by 2040, along with 150 GWh of diesel and AV Jet plants (Figure 14). The significant decline in 2030 is due to the retirement of a major electricity facility that utilises heavy fuel oil. This planned investment schedule suggests that with continued investment in heavy fuel oil electricity generating plants, approximately 100 MW in 2030, the island will have enough installed capacity to met energy demands (Figure 15).

Figure 14: Electricity Production in Barbados by Fuel Type & Energy Source under BAU Assumptions



Source: Model projections

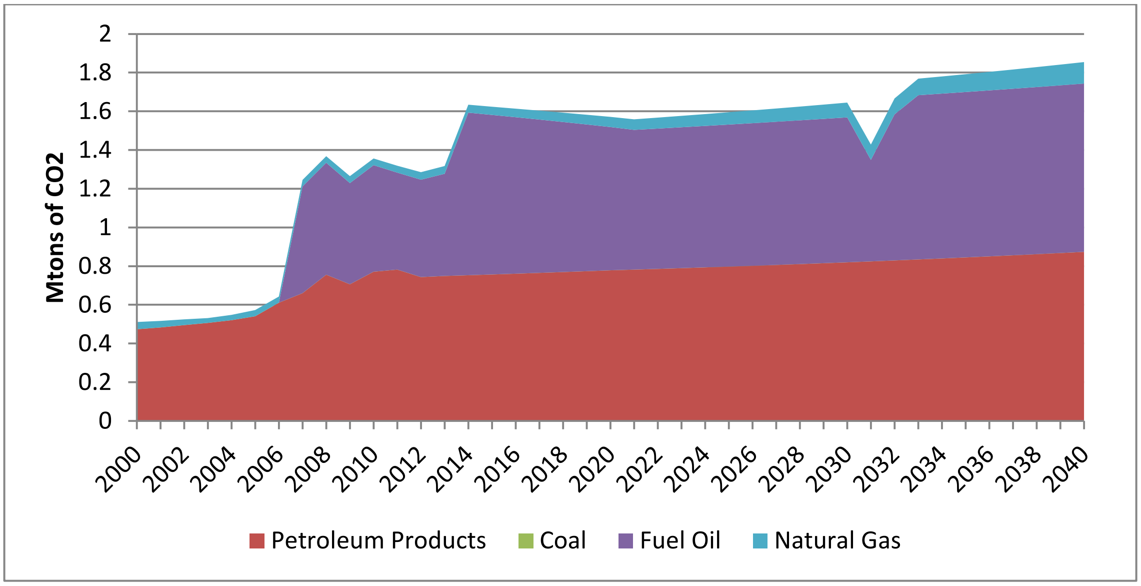
Figure 15: Electricity Demand verses Supply in Barbados under the BAU Scenario



Source: Model projections

Under the business as usual scenario, however, most of this installed electricity capacity operates through a continued dependence on fossil fuels. This would therefore lead to an increase in the CO2 emissions of the island to 1.8 million tonnes by 2040. Most of these emissions would be due to the burning of heavy fuel oil to generate electricity as well as petroleum products used in transportation and freighting. Modest growth in natural gas usage is expected due to the declining productivity of wells.

Figure 16: CO_2 Emissions from Fuel Combustion in Barbados under BAU Assumptions

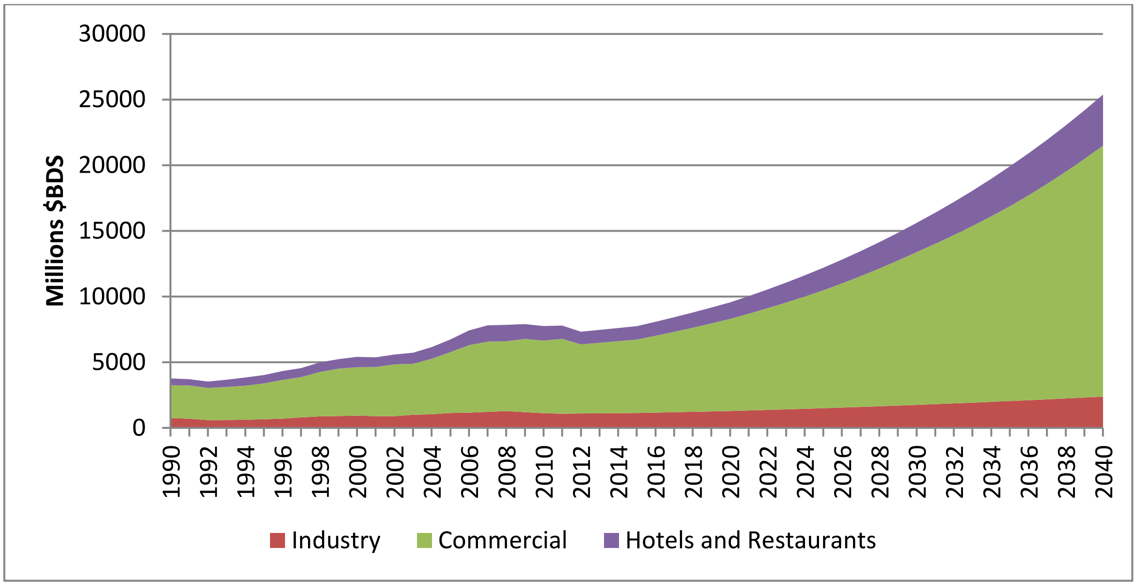


Source: Model projections

4.2 National Strategic Plan

The island's national strategic plan (GOB, 2005) targets an average annual rate of economic growth of 5% per annum, achieved through various strategic initiatives aimed at business facilitation, boosting exports, and diversification of the economic base (Figure 17). Such a rapid rate of economic growth would therefore result in a significant expansion in commercial services, to support these new industries as well as to support the tourism and industrial areas that were also targeted for further growth.

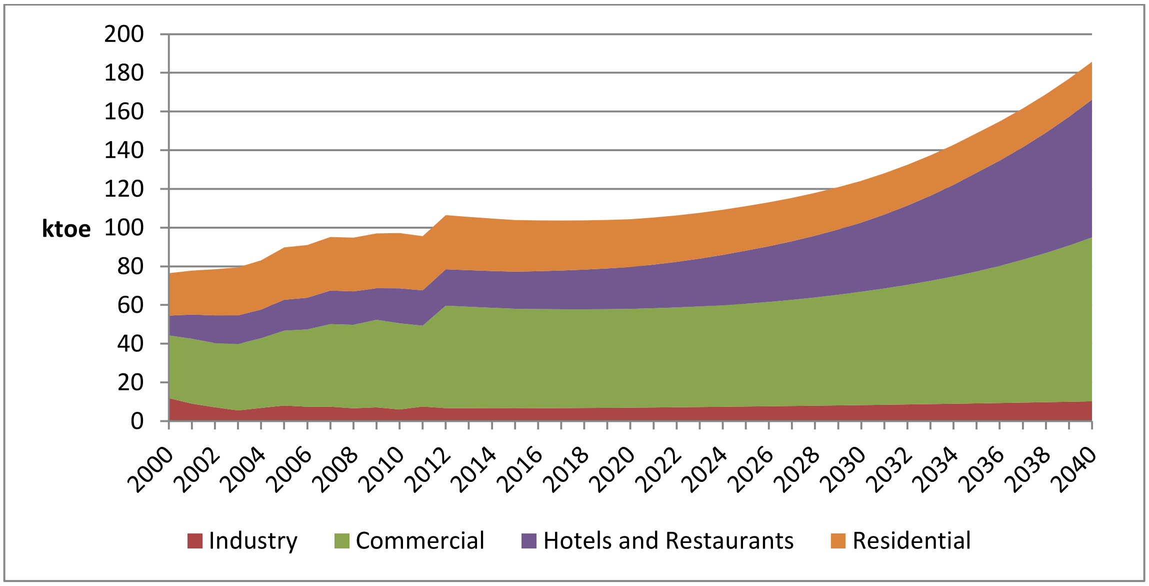
Figure 17: Projected Sectoral Economic Growth of the National Strategic Plan



Source: Model projections

The National Strategic Plan paid little attention, however, to energy efficiency. The model suggests that much of this additional growth will result in a significant growth in final energy demand (see Figure 18). Final energy demand is anticipated to rise from

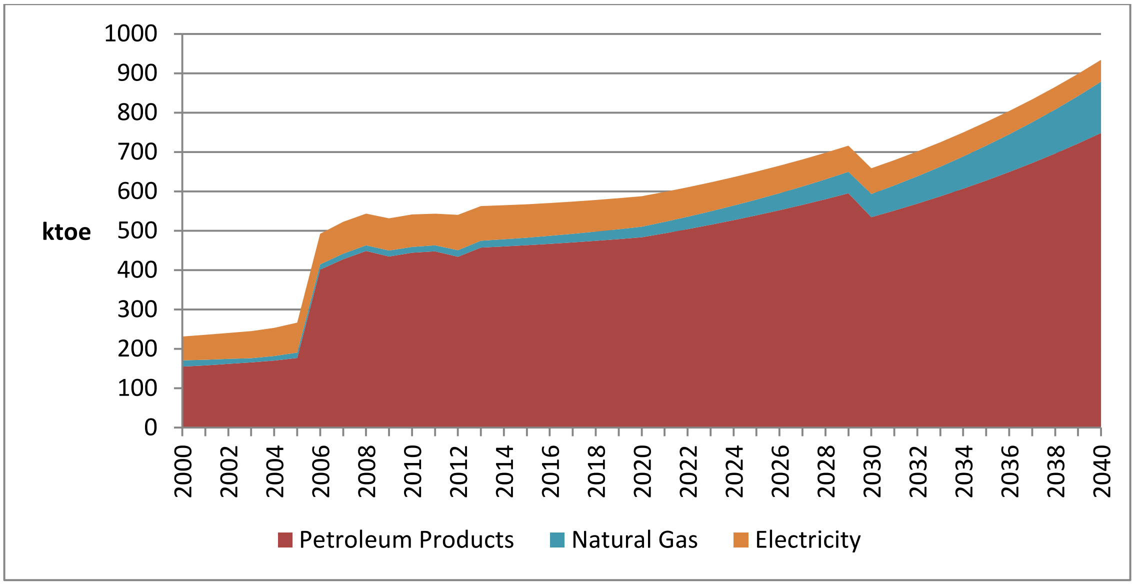
Figure 18: Final Energy Use by Sector under the National Strategic Plan



Source: Model projections

120 ktoe in the baseline scenario to 180 ktoe by 2040, largely due to a significant expansion in energy demand from the commercial as well as the hotel and restaurant industry. The National Strategic Plan (GOB, 2005) does not place a lot of emphasis on how this energy demand would be met, but given the comparative cost of natural gas, the model assumes that most of the growth in energy consumption would be shifted to natural gas (Figure 19).

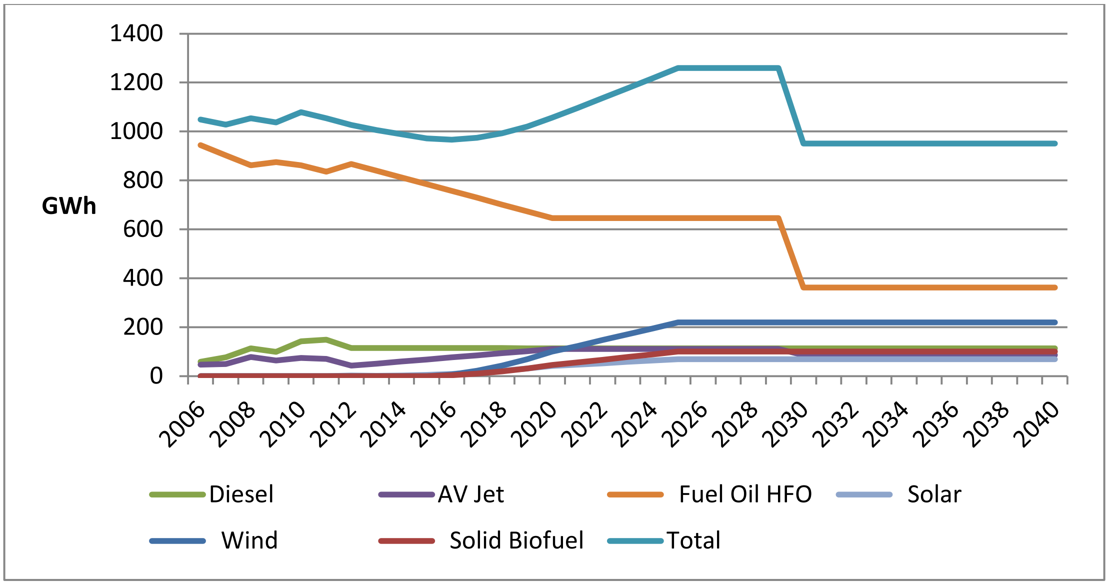
Figure 19: Fuel Consumption by Fuel Type in Barbados under National Strategic Plan



Source: Model projections

On the supply-side of the energy matrix, the Sustainable Development plan identified a number of initiatives aimed at building the renewable energy capacity of the island. In this regard, it is planned that 200 GWh of wind would be brought online along with around 100 GWh of solid biofuel (linked to the sugar industry) along with greater solar photovoltaic (largely at a non-municipal scale) electricity generation (Figure 20).

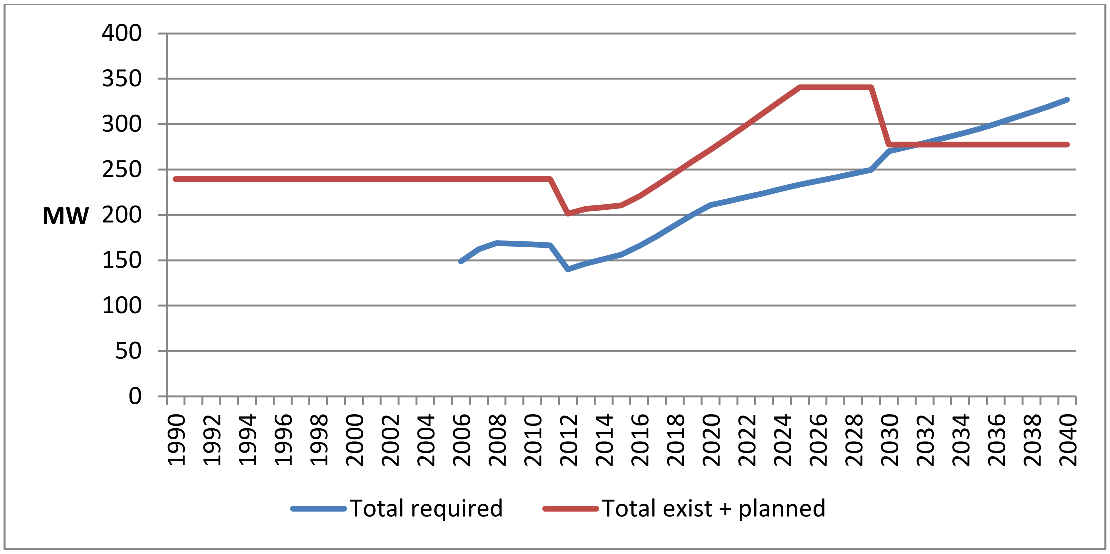
Figure 20: Electricity Production in Barbados by Fuel Source and Energy Type under the National Strategic Plan



Source: Model projections

The scenario analysis conducted using the parameters provided in the National Strategic Plan, however, results in a supply-demand mismatch in relation to electricity demand and supply. Even though the rise in electricity demand is slower than in the baseline scenario, due to greater efficiency, total required capacity will exceed total available capacity after 2030. This occurs since the planned increase in renewables in the National Strategic Plan is not enough to offset the planned obsolesce of the traditional fuel oil electricity generating plants.

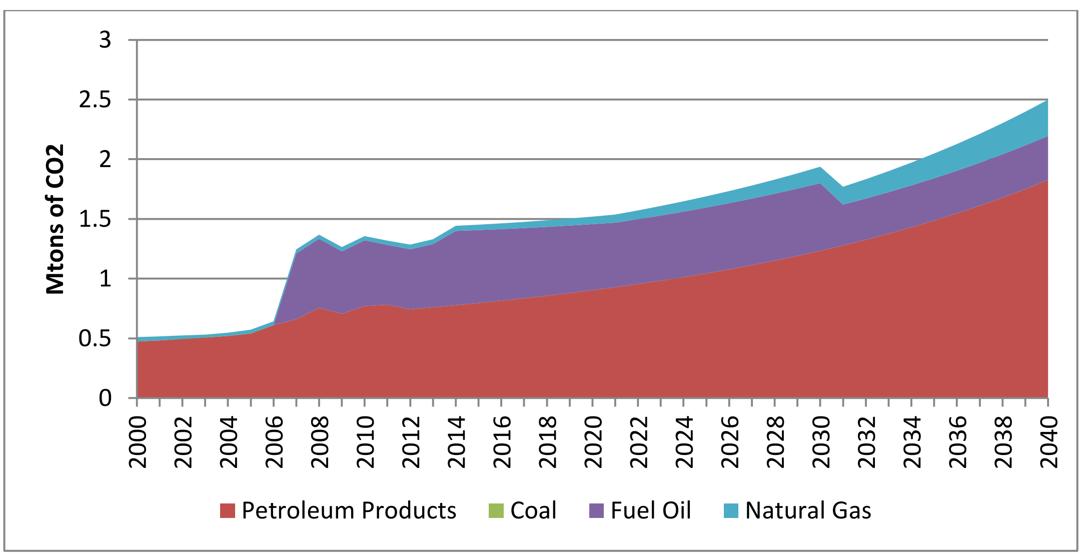
Figure 21: Electricity Demand Verses Supply for Barbados under the National Strategic Plan



Source: Model projections

Despite this additional investment in renewables and reduced investment in fossil fuels, total CO2 emissions is likely to rise relatively to the baseline scenario, largely due to the

Figure 22: Co_2 Emissions from Fuel Combustion in Barbados under the National Strategic Plan



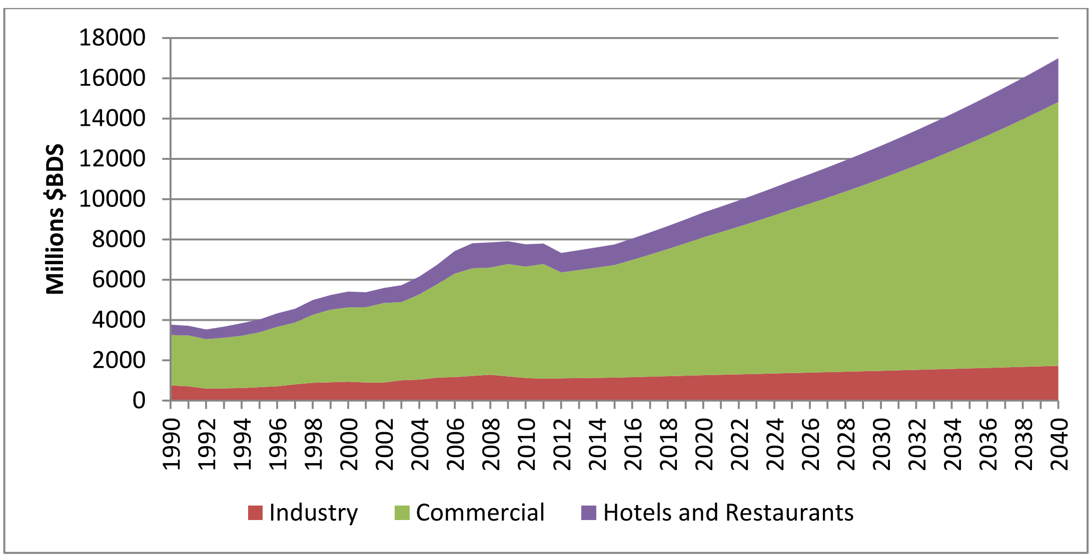
Source: Model projections

significantly faster growth in economic activity anticipated in the National Strategic Planning framework. As a result, total CO2 emissions are likely to jump to 2.5 million tonnes, compared to 1.8 million tonnes in the baseline scenario. These additional CO2 emissions will likely have implications for health(Maizlish, Woodcock, Co, Ostro, Fanai, & Farley, 2013; Woodcok, et al., 2009)and would not be in line with the island's green economy objectives identified in the National Strategic Plan.

4.3 Sustainable Energy Framework

In contrast to National Strategic Plan (GOB, 2005), the Sustainable Energy Framework(Castalia Ltd, 2010) for the island attempts to identify a specific vision of the island's energy future. The framework, however, largely ignored economic developments, making only an assumption in relation to future growth, but not any feedback and

Figure 23: Projected Sectoral Economic Growth in Barbados under the Sustainable Energy Framework



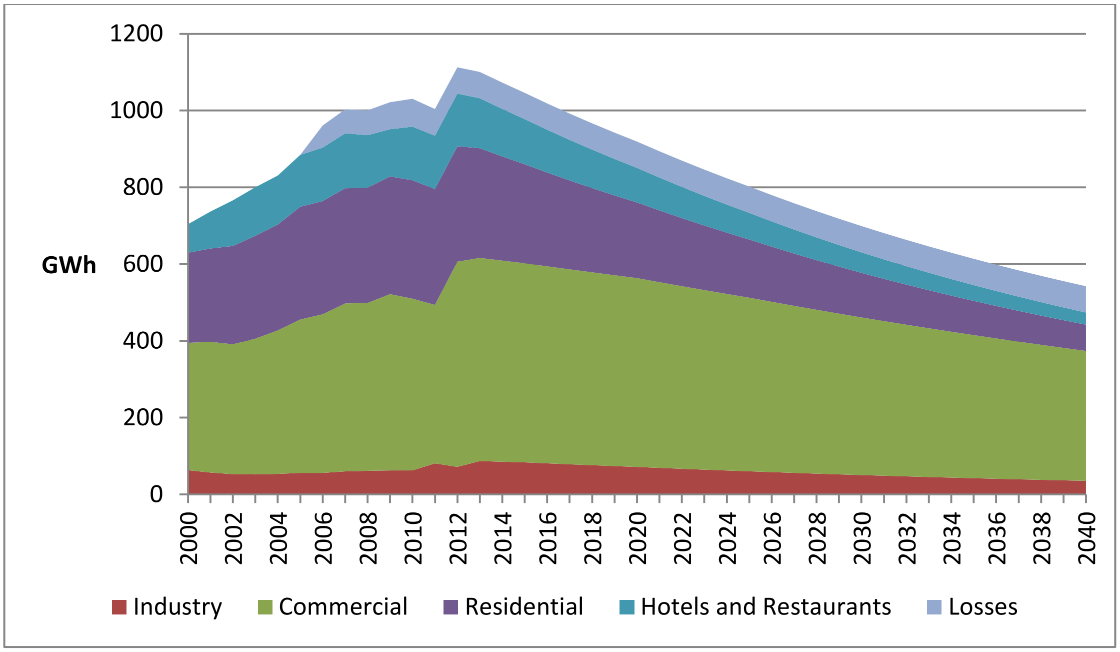
Source: Model projections

sectoral energy developments. The projected average annual rate of growth in this scenario is somewhat slower, 3 percent (Figure 23) compared to 5 percent in the National Strategic

Plan (GOB, 2005). Similar to the previous scenarios, most of this growth is anticipated to be driven by the commercial and tourism industries.

Unlike the previous two scenarios, BAU and National Strategic Plan, electricity consumption is anticipated to decline due to a significant increase in energy efficiency outlined in the plan. As a result, total electricity demand by 2040 is projected to be under 600 GWh compared to 1400 GWh in the business as usual scenario (Figure 24).

Figure 24: Electricity Consumption by Sector in Barbados under the Sustainable Energy Framework



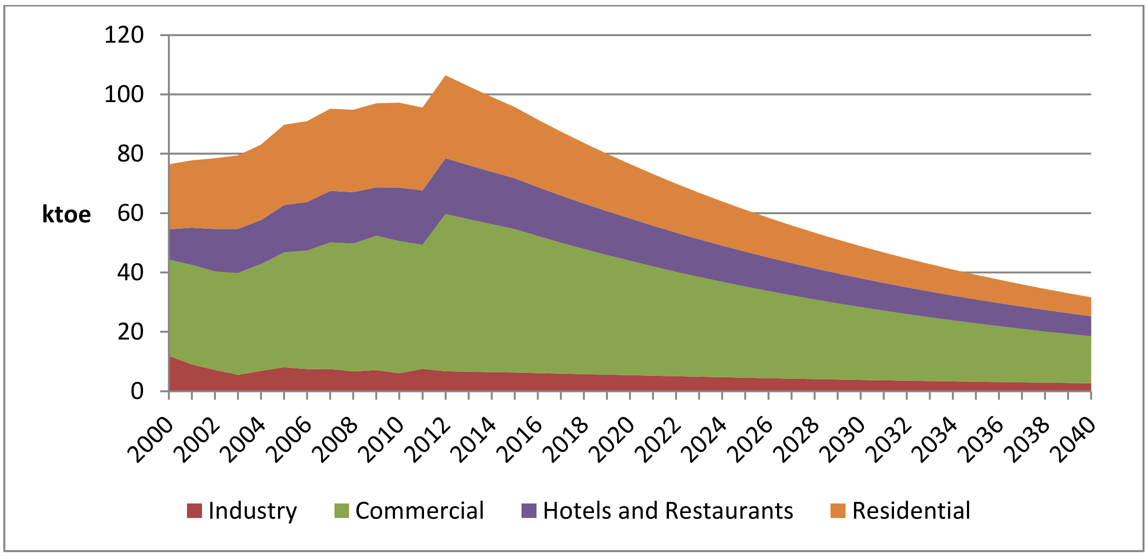
Source: Model projections

This decline in electricity demand is envisaged to emanate from energy savings primarily at the household level, hotels and restaurants, and to some extent industry. This increase in energy efficiency would also reduce final energy use relative to the baseline to just 35 ktoe, compared to 120 ktoe in the baseline scenario (Figure 25). These savings will be achieved through the implementation of energy efficiency initiatives across the various industries resulting in significant savings in terms of energy use. Initiatives included mandating energy efficiency design in the building code (Castalia Ltd, 2010) such as:

- minimum standards for equipment efficiency;
- maximum lighting density; and,
- minimum levels for wall R-values and window properties.

Other initiatives aimed more at businesses would include the establishment of a Smart Fund to provide financing for the use of renewable energy and energy efficiency technologies, tax incentives for environmentally preferred products, the phasing out of incandescent light bulbs, and the enactment of an energy labelling programme.

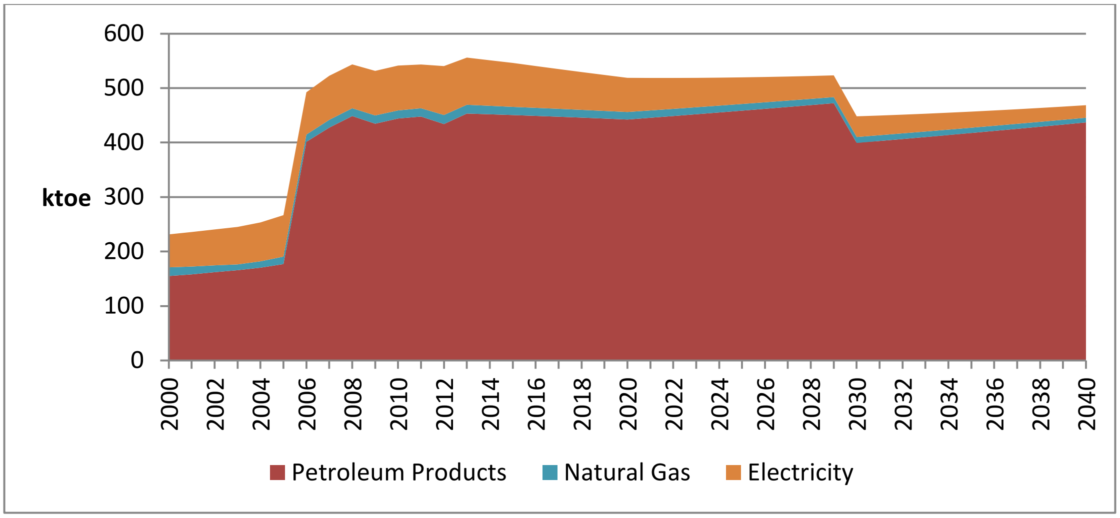
Figure 25: Sectoral Final Energy Use in Barbados under the Sustainable Energy Framework



Source: Model projections

These energy savings also result in a significant reduction in fuel consumption of petroleum products primarily used in the generation of electricity. As a result, total fuel consumption falls from over 700 ktoe in the baseline to just over 450 ktoe, if the policies highlighted in the sustainable energy framework document are implemented. In addition, these energy efficiency and renewable energy initiatives would also put less pressure on the demand for natural gas and electricity. One glaring omission of the

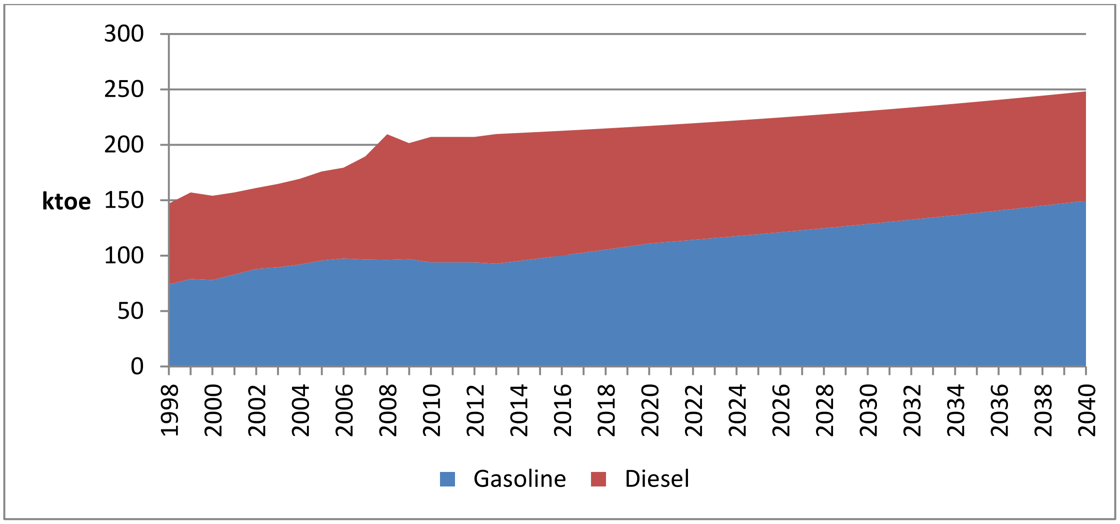
Figure 26: Fuel Consumption by Fuel Type in Barbados under the Sustainable Energy Framework



Source: Model projections

document, however, is the use of petroleum products in transportation. If greater emphasis could be placed on reducing the amount of petroleum products used in transportation, even greater savings, in terms of fuel consumption, could have been attained. Figure 27 suggests that based on current population and usage trends, fuels used in transportation would continue to rise over the medium-term to reach about 250 ktoe, or more than half of all petroleum products consumed in the island.

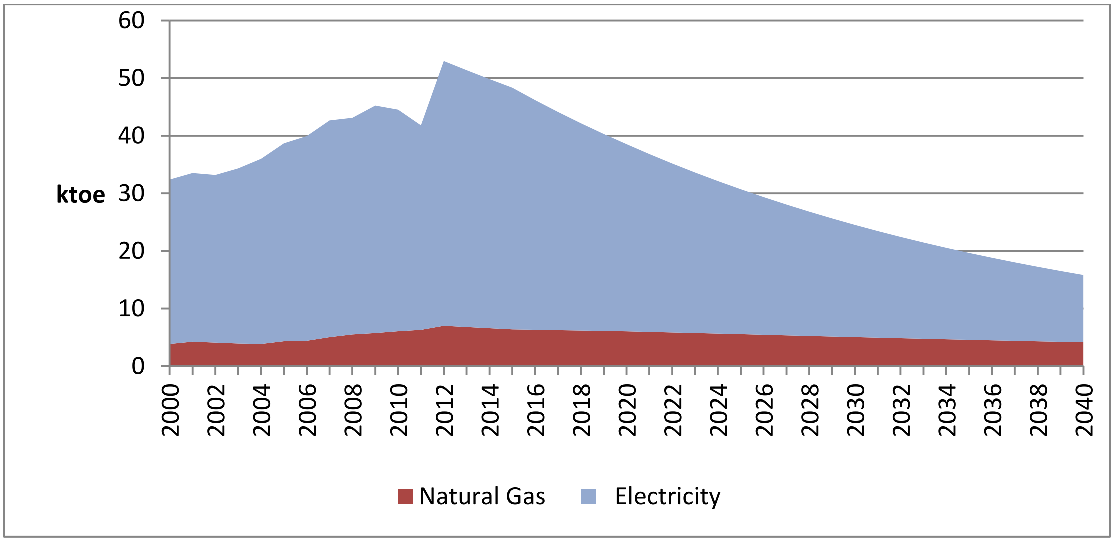
Figure 27: Transport Sector Fuel Use under the Sustainable Energy Framework



Source: Model projections

Most of the reductions in overall energy use are expected to be driven by declines in the use of energy by the commercial sector, households and to some extent tourism.

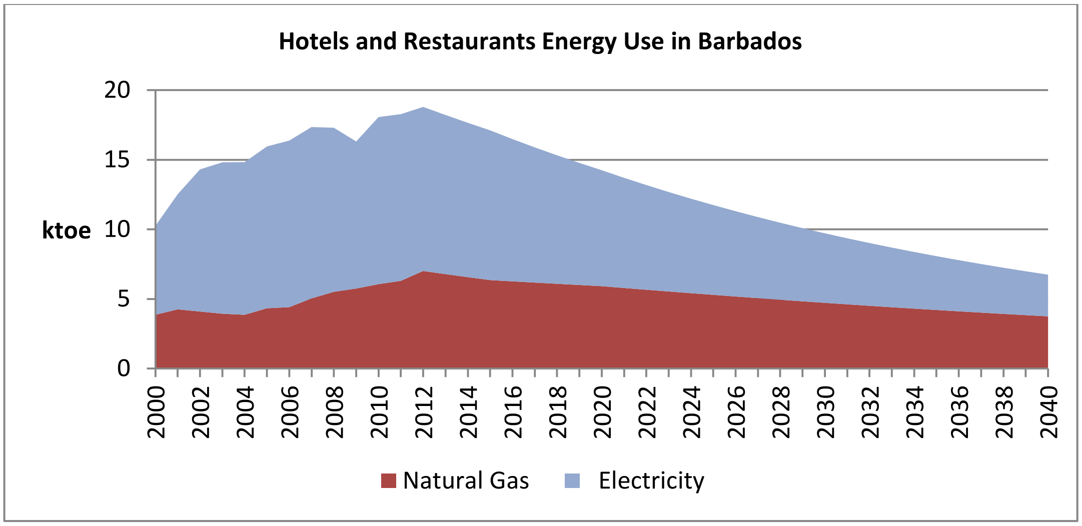
Figure 28: Commercial Sector Energy Use in Barbados under the Sustainable Energy Framework



Source: Model projections

Due to the greater uptake of various energy efficiency technologies, energy use in the commercial (Figure 28) and hotel and restaurant (Figure 29) industries are anticipated to fall from a peak of just over 50 ktoe to just 15 ktoe by 2040. Technologies highlighted in Castalia Ltd (2010) included the use of variable frequency drives (particularly in water pumping), the use of efficient split A/C systems, T8 fluorescent lamps with occupancy sensors, efficient chillers, T5 high output fluorescent lamps, LCD computer monitors, efficient retail refrigerators, LED street lighting as well as solar LED street lighting.

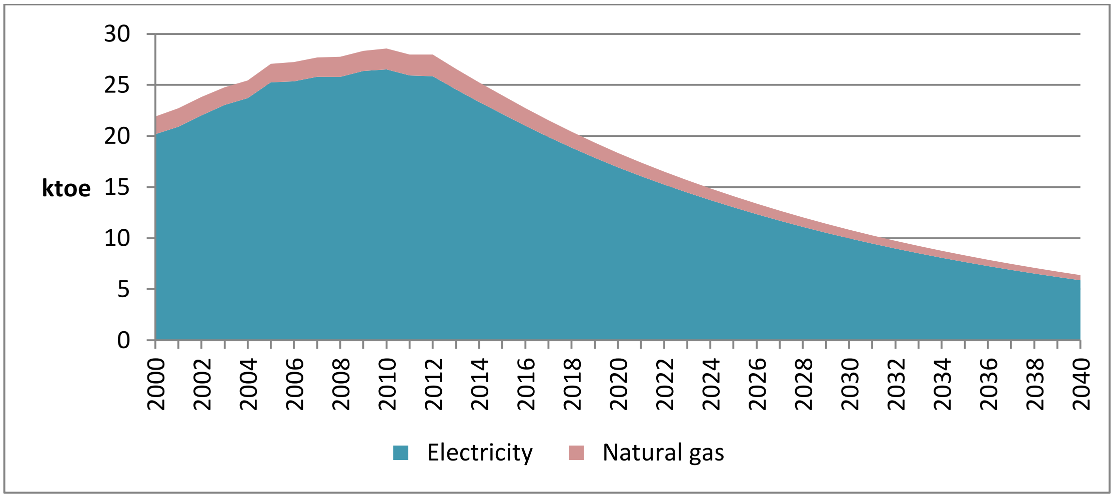
Figure 29: Hotels and Restaurants Energy Use in Barbados under the Sustainable Energy Framework



Source: Model projections

Residential energy use also falls significantly in this scenario. In the sustainable energy scenario, by 2040, residential energy use falls from a peak of 28 ktoe to just 6 ktoe through the use of various energy saving technologies. In relation to energy saving technologies, some options targeted included the greater use of compact fluorescent lamps, power monitors, efficient window air conditioning systemsand effficient residential refrigerators.

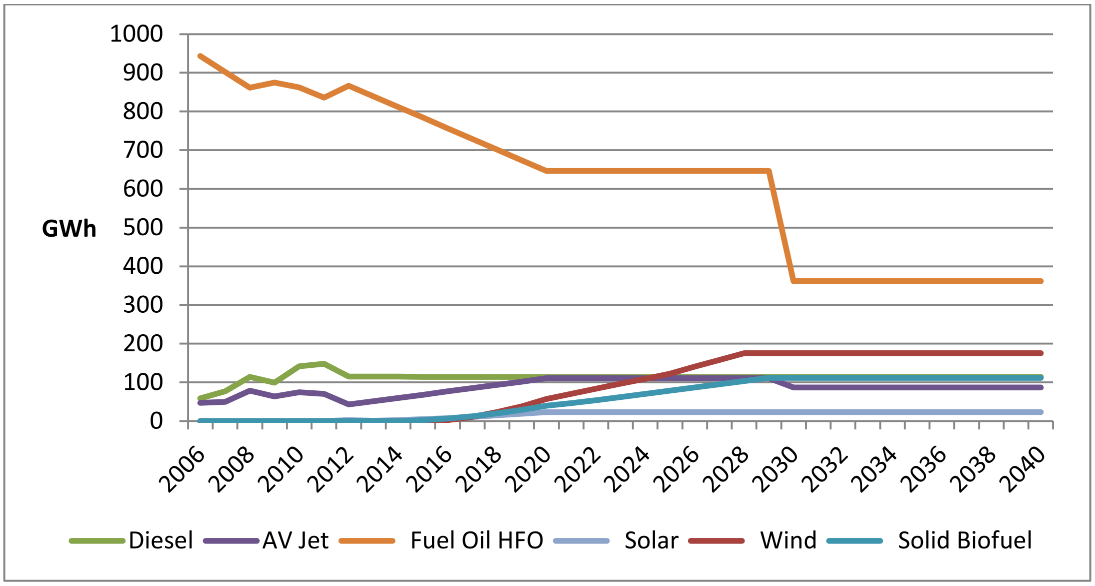
Figure 30: Residential Energy Use in Barbados under the Sustainable Energy Framework



Source: Model projections

The plant mix identified in Castalia Ltd (2010) targeted a greater utilisation of solar and wind technologies in the generation of electricity along with some traditional fossil fuel plants to provide base load and offset the variability that characterises renewable energy sources (Figure 31). In addition to solar and wind, solid biofuel, linked with the sugar industry, was also targeted as a source of energy. The total amount of energy available for supply from these sources would therefore be between 200 and 250 MWh between 2015 and 2040. This amount of electricity production would be more than enough to meet projected demands, once the energy saving initiatives highlighted above are adopted. Indeed, the simulation suggests that the island may be overinvesting in electricity production, and can afford to eliminate another 100 MWh of electricity production through the use of energy saving technologies at the household level and in businesses.

Figure 31: Electricity Production by Fuel Type and Energy Source in Barbados under the Sustainable Energy Framework



Source: Model projections

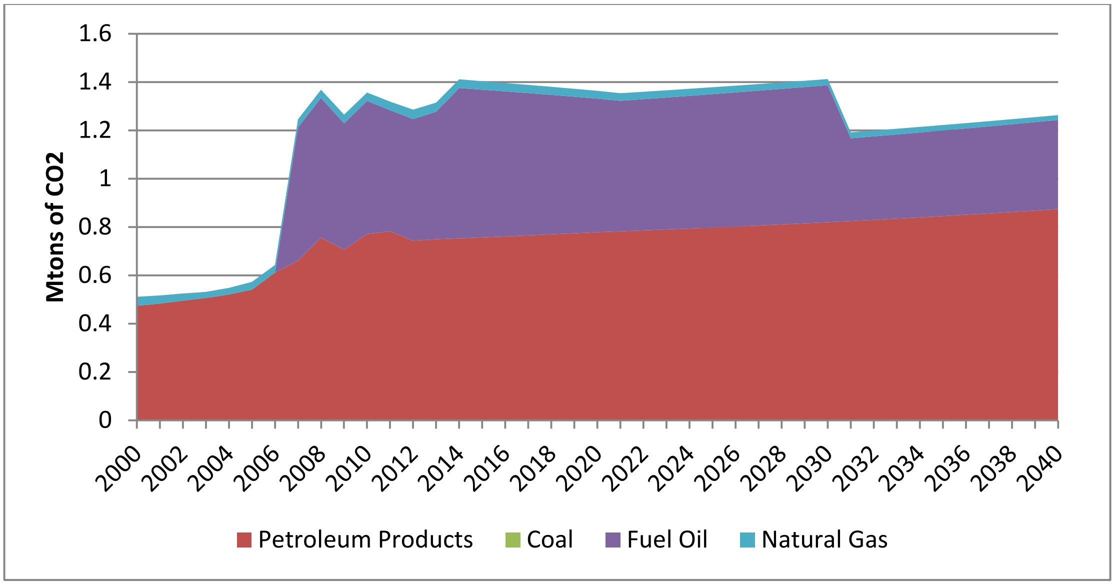
Figure 32: Electricity Demand verses Supply in Barbados under the Sustainable Energy Framework

Source: Model projections

The modelling framework used in this study, which links the energy and economy sides of the economy shows the benefits of undertaking such long-term simulations. Such overinvestment in electricity supply could be redirected to alternative uses that better target the developmental challenges faced by the island.

In addition to a reduction in required electricity production capacity, the initiatives highlighted in the Sustainable Energy Framework Document (Castalia Ltd, 2010) would also lead to a significant decline in the CO_2 emissions relative to the baseline scenario. In the baseline scenario, it was forecasted that CO_2 emissions would reach 2.5 Mtons by 2040. With the adoption of renewable and energy saving technologies, emissions would fall to just 1.2 Mtons. Such a reduction would support the green economy

Figure 33:CO_2 Emissions from Fuel Combustion in Barbados under the Sustainable Energy Framework



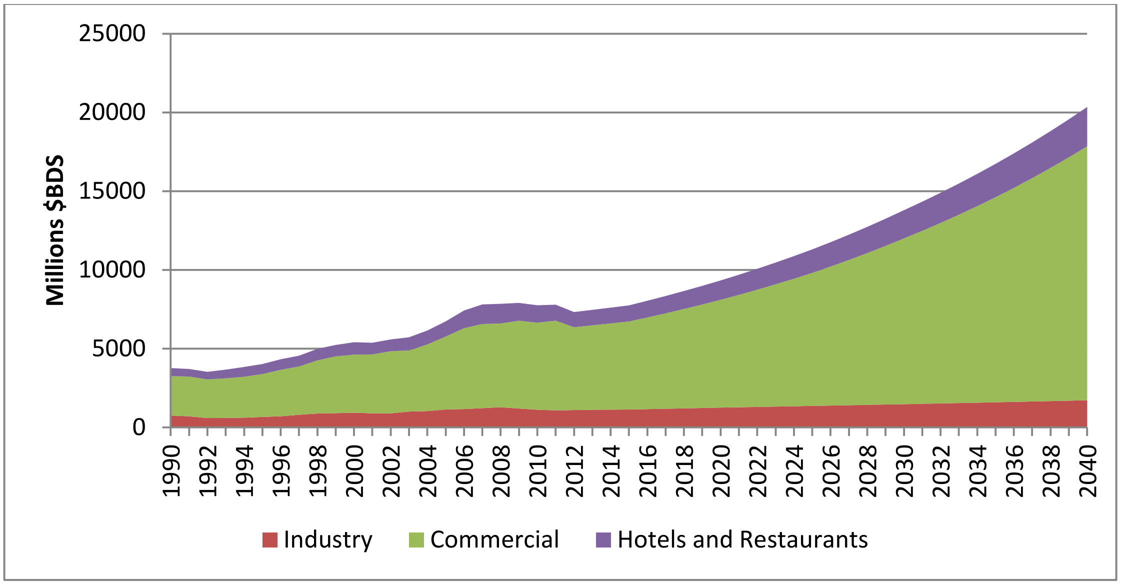
Source: Model projections

strategy/goals of the island, and enhance local air quality(Moore, et al., 2012).

4.4 Barbados Growth and Development Strategy

In 2012, as Barbadian policymakers struggled to keep the island from falling into its deepest recession ever, the Government published a Growth and Development Strategy document (GOB, 2012). The policy document was not as wide-ranging as the island's National Strategic Plan (GOB, 2005). However, it put forward a number of strategies targeting both growth as well as the green economy. The Growth and Development Strategy (GOB, 2012) had a growth rate target of 4 percent (Figure 34), 1 percent more than in the business as usual scenario and the Sustainable Energy Framework Document (Castalia Ltd, 2010), but 1 percent lower than the rate of growth targeted in the island's national strategic plan (GOB, 2005). This additional growth is assumed to occur mainly in the commercial as well as hotel and restaurant industries.

Figure 34: Projected Economic Growth under the Barbados Growth and Development Strategy Scenario

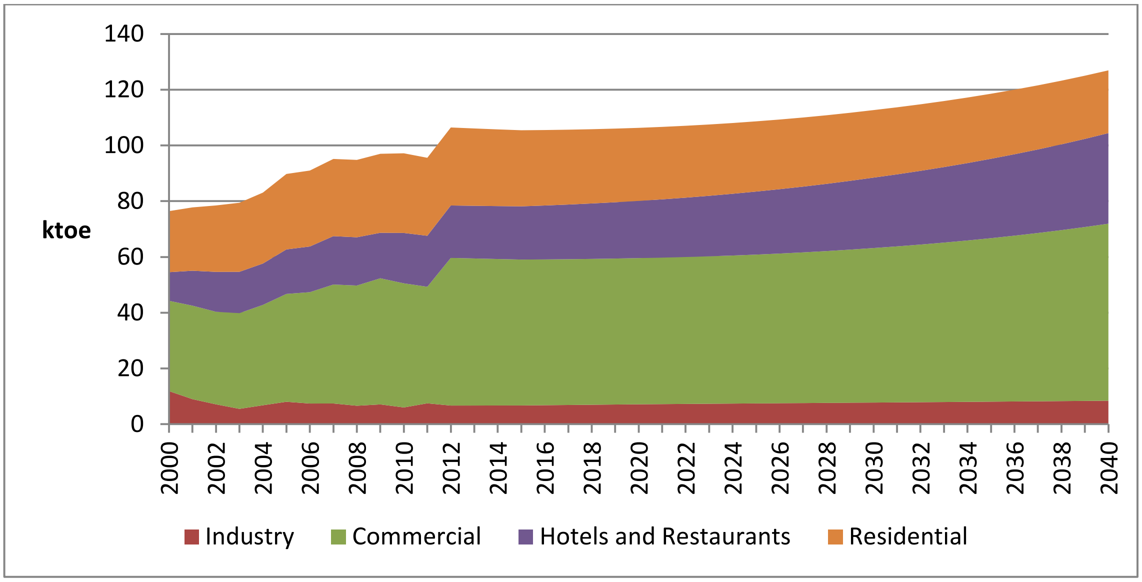


Source: Model projections

The Growth and Development Strategy document (GOB, 2012) was primarily aimed at addressing the fiscal challenges facing the island. However, There were some policies aimed at reduced the islands fuel imports. These initiatives primarily aimed at enhancing energy efficiencies, enhancing the use of renewable energies as well as the potential deployment of solar and bio-fuel for electricity generation.

Given the increased growth projected in the Growth and Development Strategy scenario, the total consumption of energy is expected to rise to 126 ktoe, compared to less than 118 ktoe in the business as usual scenario (Figure 35). Based on the growth initiatives highlighted in GOB (2012) most of this additional energy will be consumed by the commercial as well as hotel and restaurant industry. Total fuel consumption,

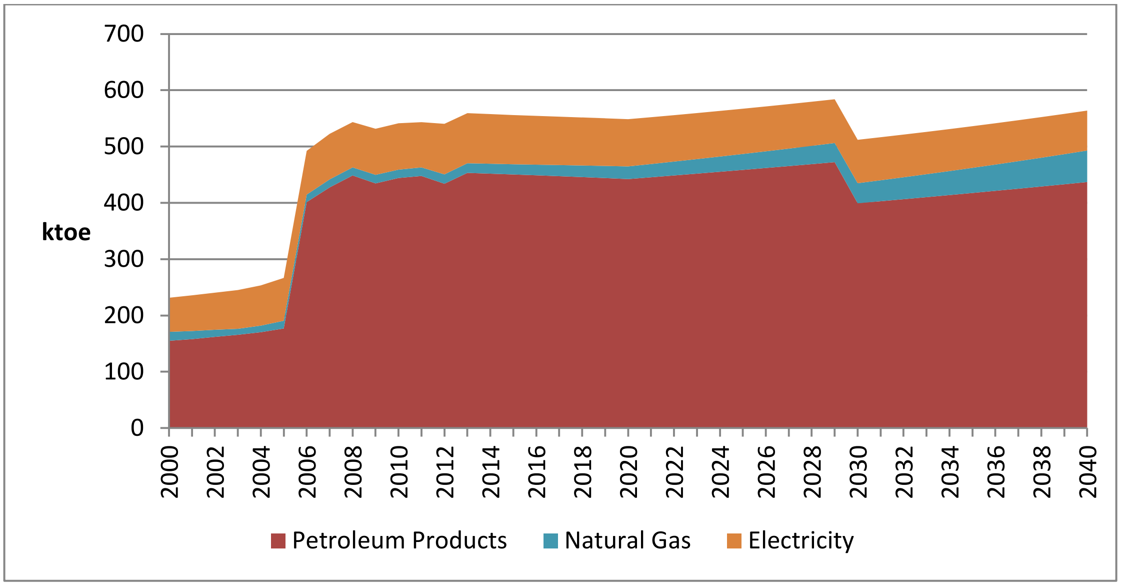
Figure 35: Sectoral Final Energy under the Barbados Growth and Development Strategy Scenario



Source: Model projections

however, would be 22 percent lower than in the business as usual scenario (Figure 36), due to various renewable energy and energy saving initiatives. In relation to energy conservation strategies, GOB (2012) recommended the implementation of a public education and awareness campaign to promote sustainable energy practices, building standards that encourage the conservation of energy, energy efficiency surveys and audits of government buildings, and the use of an incentive scheme to support the utilisation of energy efficient equipment.

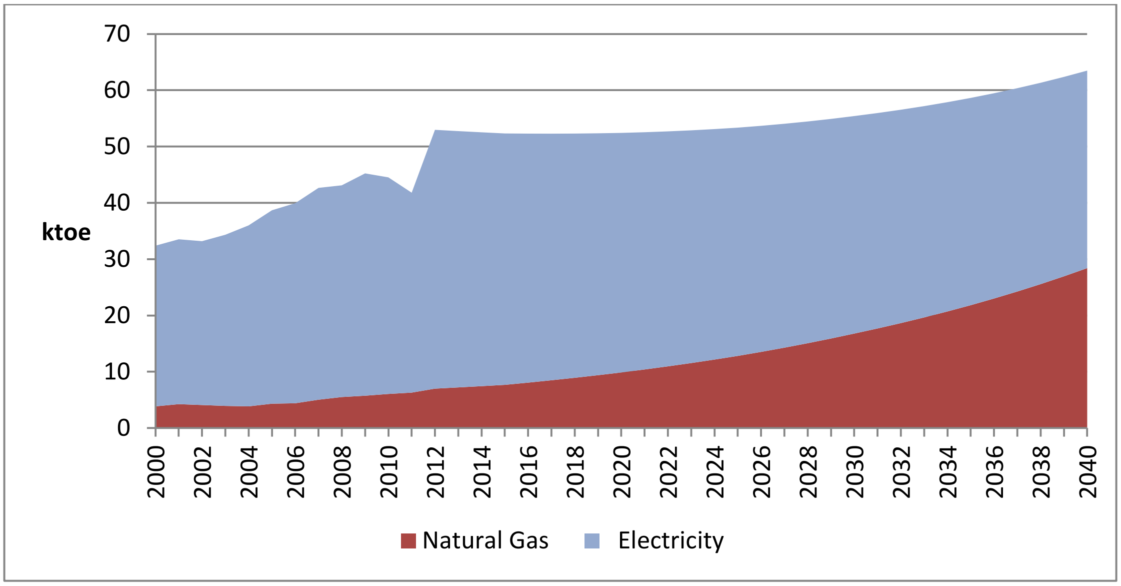
Figure 36:Fuel Consumption by Fuel Type under the Barbados Growth and Development Strategy



Source: Model projections

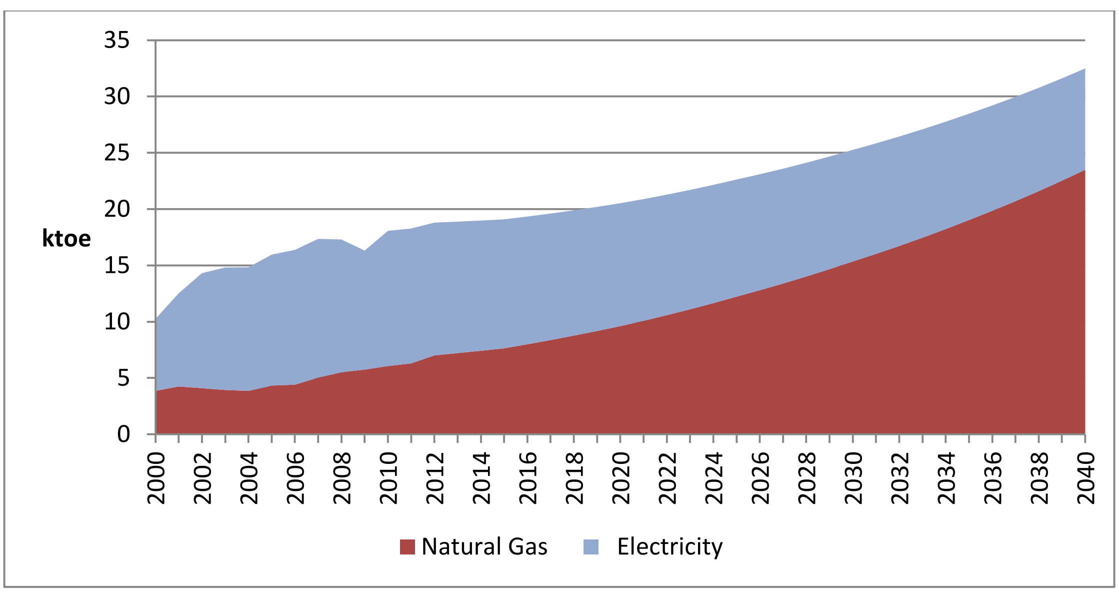
The energy saving initiatives highlighted above are therefore expected to partially offset the additional energy demand for the commercial as well as hotel and restaurant industries occurring due to the projected faster rate of growth. Nevertheless, energy demand is still anticipated to be approximately 7% higher in the Growth and Development Strategy scenario relative to the baseline scenario (Figure 37 and Figure 38).

Figure 37:Commercial Sector Energy Use under the Barbados Growth and Development Strategy



Source: Model projections

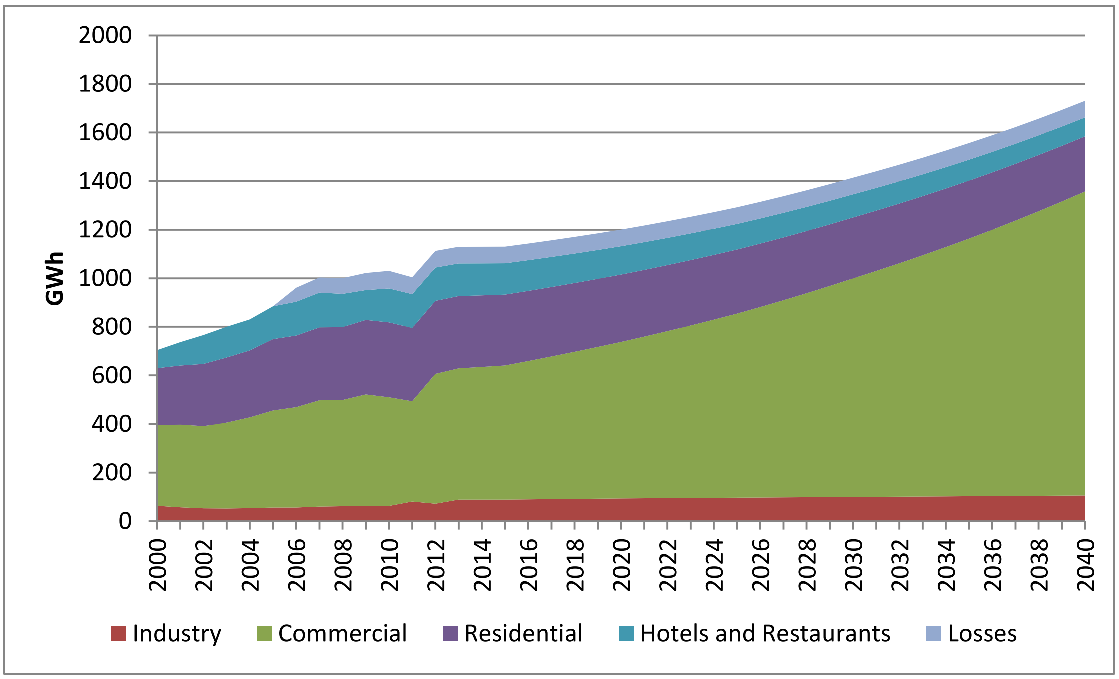
Figure 38: Hotel and Restaurant Energy Use under the Barbados Growth and Development Strategy



Source: Model projections

Given the growth in energy demand anticipated in the commercial as well as tourism and restaurant industries, total electricity consumption is projected to rise to just under 1600 GWh in the Growth and Development Strategy scenario. This represents a 23% increase in electricity consumption for the commercial sector relative to the baseline scenario and a 16 percent increase in total electricity consumption.

Figure 39: Electricity Consumption by Sector under the Barbados Growth and Development Strategy Outlook



Source: Model projections

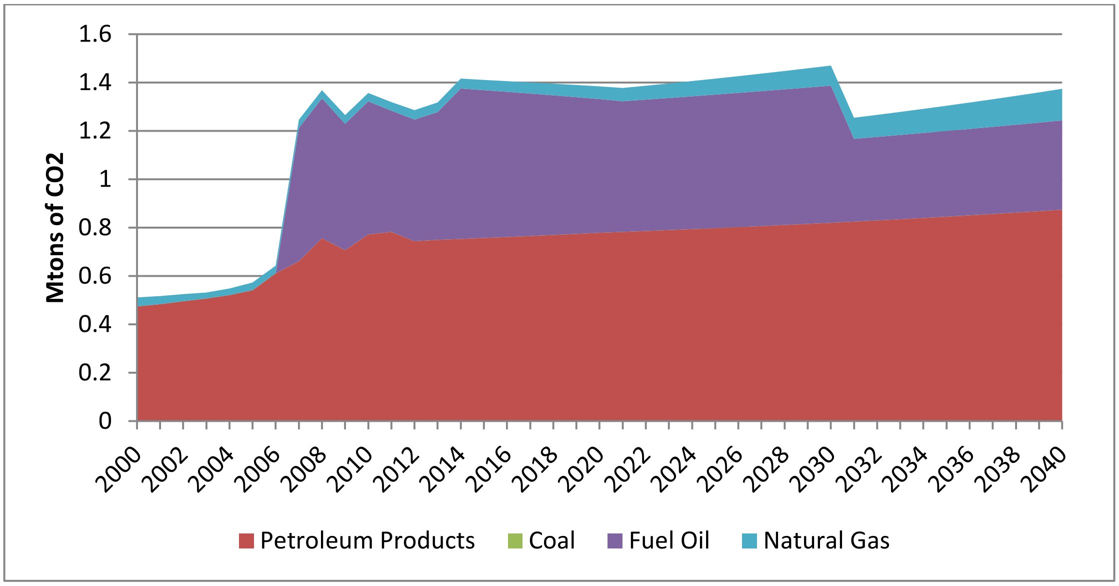
As a result of the additional growth and therefore energy demand anticipated in this Growth and Development Strategy Scenario, without the necessary supporting investment in electricity production, total required electricity exceeds total production capacity by 2030. This indicates that this plan would be frustrated without further investment in either renewable or conventional electricity generating technologies.

Figure 40: Electricity Demand Verses Supply under the Barbados Growth and Development StrategyScenario

Source: Model projections

The reduction in fuel consumption highlighted earlier, however, would result in a reduction in CO_2 emissions in the Growth and Development Strategy Scenario.

Figure 41: Co2 Emissions From Fuel Combustion under the Barbados Growth and Development Strategy Outlook



Source: Model projections

In this scenario, CO_2 emissions would be expected to reach 1.4 Mtons compared to over 1.8 Mtons in the business as usual scenario, a 26 percent reduction. This mainly occurs due to the reduced use of fuel oil in electricity production as well as energy saving initiatives at the household and business sectors.

5 Conclusions

The main objective of this paper was to develop and use a modelling framework that could assess the long run consistency of economic and energy policies. The study therefore develops the Barbados-LINDA, which is long run model of energy development that accounts for both supply-side energy features as well as demand-side changes, particularly in relation to energy efficiency. The model is then employed to assess the consistency of three policy planning documents produced by/for the Government of Barbados: (1) National Strategic Plan; (2) Sustainable Energy Framework; and, (3) Growth and Development Strategy.

The modelling exercise conducted suggests that there were demand-supply mismatches under all three plans. The National Strategic Plan as well as the Growth and Development Strategy, if implemented, would result in the demand for electricity exceeding the available supply by 2040, while the Sustainable Energy Framework would lead to a significant over-investment in electricity capacity (100 MWh). This analysis suggests that policymakers should attempt to integrate all resource segments (water, energy and land) when developing plans for economic growth. While it can be argued, that having too much capacity is superior to having too little capacity, such an outcome also results in misallocation of resources and in a developing country, such resources could be better allocated to address other development challenges.

Of the three scenarios considered, the Sustainable Energy Framework scenarios results in the largest savings for the island. In this scenario, fuel consumption falls from 710 ktoe in the baseline scenario to just 470 ktoe by 2040. Using 2014 prices from the International Monetary Fund's World Economic Outlook(International Monetary Fund, 2015), this amount to an annual saving of US$16 million in energy imports. For a country dependent on imported fossil fuels, such savings can not only lead to an improvement in the external current account balance, but can also reduce vulnerability to oil price shocks. Much of the savings in this scenario emanate not only from the use of renewable/alternative energy sources, but to large degree from the utilisation of energy saving technologies. Many of these technologies are already feasible and have very short payback periods. Some of the technologies identified by Castalia Ltd (2010) are Compact Fluorescents Lamps (CFLs), power monitors, premium efficiency motors, efficient Air Conditioning (AC) systems, variable frequency drives and efficient chillers.

Given the findings obtained in this study, the authors recommend that policymakers in Barbados might want to utilise a more integrated approach to policy development in the future. This would ensure the consistence of future initiatives as well as ensure expected growth paths are not frustrated by resource limitations. The Barbados-LINDA could be utilised to conduct such analyses.

Future research should potentially consider both investment and energy prices in the assessment. By utilising estimates of projected future energy costs along with the investment costs of various energy initiatives, the model could then be utilised to identify the least-cost investment path consistent with growth and development targets. This present paper largely focussed on the economic implications for energy demand. However, potential sociological changes can also impact significantly on energy demand. Future research could consider various scenarios that incorporate sociological assumptions independently as well as in collaboration with the economic and energy assumptions investigated in this study.

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