Chapter 5

Energy: the Key to a Cleaner, More Prosperous Caribbean

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5.1 Introduction

Commonwealth Caribbean states face several environmental challenges that prevent them achieving sustainable development. The occurrence of natural disasters and the effects of climate change on tourism and agriculture are negatively affecting Caribbean countries, as these industries provide a high percentage of GDP. Additionally, natural disasters can disrupt development prospects, as funds are diverted to deal with the immediate aftermath of a disaster. The role of energy is important in so far as increased access to energy can facilitate economic growth and is integral to human development. Given the aforementioned effects of climate change on the economy, there has been a renewed emphasis on reducing small states' reliance on fossil fuel imports. This in turn has led to the examination of renewable energy possibilities and the issue of energy security.

The transformation of the Caribbean's energy sector to one based on clean, sustainable sources of indigenous energy will have a wide-reaching impact on the region. This impact will extend much further than the creation of resilient energy systems. It will create employment and rejuvenate economic sectors that have suffered in recent years, such as tourism, manufacturing and transportation. It will provide vital experience of the region's ability to work together, leading to better regional understanding and cohesion. Perhaps most importantly, the Caribbean successfully pursing a sustainable energy system will send a strong message to the rest of the world that tackling climate change and transitioning from an almost 100 per cent fossil fuel-based energy system to a clean, sustainable energy system is indeed possible.

This study is based on a desktop review of existing literature related to the Caribbean energy sector, and on telephone interviews with the following Caribbean energy sector stakeholders:[1]

- CARICOM energy unit;
- Organization of American States (OAS);
- Caribbean Development Bank (CDB);
- Ministry of Environment and Housing – The Bahamas;
- Ministry of Finance, Planning, Economic Development, Trade, Energy and Cooperatives – Grenada;

- Ministry of Sustainable Development, Energy, Science and Technology – Saint Lucia;
- Office of Utilities Regulation – Jamaica;
- Ministry of Energy and Energy Industries – Trinidad and Tobago;
- Regulated Industries Commission – Trinidad and Tobago;
- The Energy Division, Ministry of Finance, Economic Affairs, and Energy – Barbados.

The study also involved the use of an online survey, with 31 responses from Caribbean energy sector stakeholders, including:

- Deutsche Gesellschaft für Internationale Zusammenarbeit;
- European Union;
- national government energy agencies;
- national regulators;
- university energy experts;
- regional utilities;
- United States Agency for International Development (USAID);
- World Bank;
- Worldwatch Institute.

5.2 Review of energy sector strategies

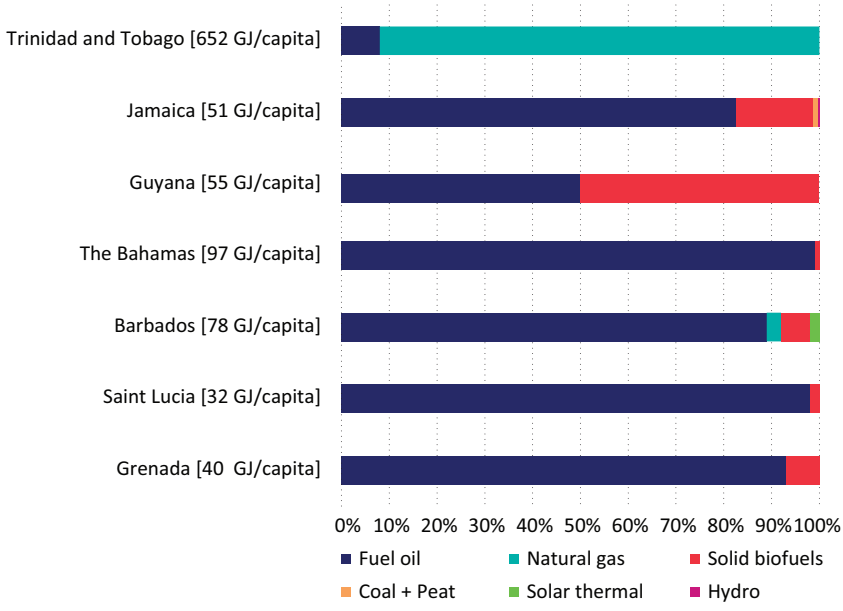
This section first discusses the status of the regional energy sector, before summarising the strategies and resilience of the target countries. There then follows a review of the international sustainable energy environment, determining both emerging trends and risks, before assessing the ability of existing strategies to foster sustainable growth.

5.2.1 Regional strategy

Figure 5.1 shows that all of the selected target countries have a primary energy supply dominated by oil products (heavy fuel oil and diesel), which is predominantly used for electrical power able to be quickly dispatched from low-speed diesel generators (this means that they are able to quickly increase or decrease their electrical output in response to changes in electrical demand, a necessary quality for isolated energy systems). The exception is Trinidad and Tobago, the primary producer and exporter of petroleum products in the Caribbean, which converted most of its generation capacity to natural gas during the 1990s.

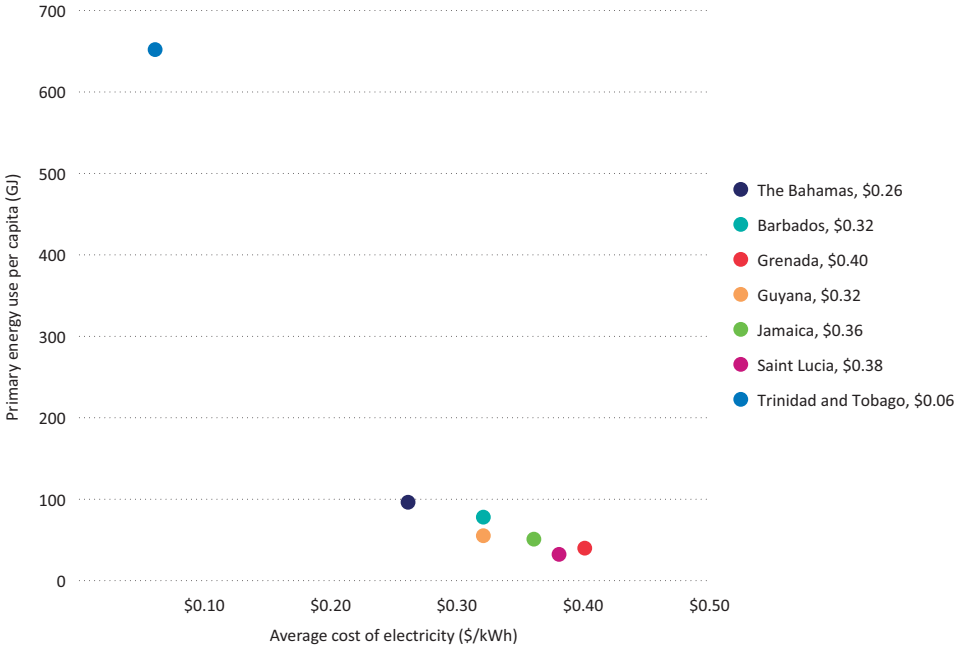
The reliance on oil products, combined with small economies of scale, has left Caribbean nations with some of the highest electricity prices in the world and exposes their already-fragile economies to increasing and volatile international oil prices and increasing electricity costs (see Figure 5.2). This has been the case even when taking into consideration the favourable financing arrangements of the PetroCaribe

Figure 5.1 Primary energy share among the target countries



Source: International Renewable Energy Agency (IRENA) 2012a

Figure 5.2 Primary energy use per capita versus average cost of electricity (US$/kWh)



Source: Inter-American Development Bank (IDB) 2012

programme. This programme provides Venezuelan oil and oil products at preferential financing terms to 17 member states across the Caribbean and Central America (PetroCaribe 2015). Commonwealth and CARICOM member states that are signed up to this agreement include Antigua and Barbuda, The Bahamas, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, St Kitts and Nevis, Saint Lucia, St Vincent and the Grenadines, and Suriname. Trinidad and Tobago and Barbados are not members of the PetroCaribe agreement. It should be pointed out that the PetroCaribe deal is vital to Haiti, given that there are no alternative financing sources and little progress has been made in reducing structural vulnerabilities in the energy sector. While the PetroCaribe programme has not experienced any major problems since it was first created in 2005, its future is currently uncertain as Venezuela grapples with its own economic challenges, including high inflation and commodity shortages (COHA 2014). Subsidy schemes such as the PetroCaribe deal help support the existing, high fossil-fuel share in the Caribbean energy sector and act as a barrier to renewables. Energy subsidies in the fossil fuel sector hold back the region's long-term growth and competitiveness, both by diverting resources away from other spending priorities and by discouraging efficiency-enhancing investment in the energy sector and distorting incentives to innovate.

The US Geological Survey splits the Commonwealth Caribbean region into four geological regions; in particular, those regions with geological features suggesting oil and gas deposits (USGS 2012). Table 5.1 shows these geological regions, along with the undiscovered, technically recoverable oil, natural gas and natural gas liquids for each region. Note that these regions include countries and territorial waters beyond those considered in this report. These four regions account for approximately 5 per cent of the undiscovered oil and gas in the Caribbean and South America combined.

According to Vella (2012), the main offshore areas of focus in the Caribbean are Trinidad and Tobago, Jamaica, The Bahamas and Barbados. Given its existing production infrastructure, the Columbus basin off Trinidad and Tobago is considered the least risky frontier in the Caribbean. In 2011, the country produced 135,000 barrels per day of oil, and in 2010 the country produced 42 billion cubic metres of natural gas, more than three times the level seen in 2000. British Petroleum Trinidad

Table 5.1 Caribbean assessment results for undiscovered, technically recoverable oil, gas and natural gas liquids (95 per cent chance of at least the amount tabulated)

Province name	Oil (million barrels)	Natural gas (billion cubic metres)	Natural gas liquids (million barrels)
Tobago Trough	0	185.7	22
Barbados Accretionary Prism	22	119.4	93
North Cuba Basin & Greater Antilles Deformed Belt	1,185	56.8	170
The Bahamas Platform	554	39.6	53
Total	**1,761**	**401.5**	**338**

Source: USGS (2012)

and Tobago has been the major player in Trinidad and Tobago since 1969. Currently, Jamaica has no history of production of its own, despite trying hard to encourage interest in its offshore acreage over the years. In 2014, the government secured a production-sharing agreement with Tullow Oil to explore the Walton Basin and Morant Basin areas, covering 32,065km^2. The Bahamas could hold up to 4.3 million barrels of oil. Although the country has been trying to get some drilling under way for some time, it has so far failed to attract any interest. Onshore oil and gas production have existed in Barbados since the early 1900s (see section 5.2.2), and Barbados's government has opened large parts of the country's offshore area for bidding during 2015. Despite the current low oil-price environment, Barbados is keen to encourage further exploration of its offshore acreage, reported to be around 2.5 million barrels of oil reserves and 142 million cubic metres of natural gas reserves.

The recent drop in the price of oil has introduced uncertainty over the general pursuit of oil and gas reserves throughout the region, in particular in current non-producing countries (Vella 2015), but also in Trinidad and Tobago, which has stepped up developments in its renewable energy sector since 2012 (Sookraj 2015).

Figure 5.1 also shows the primary energy use in the selected countries and highlights the vast difference in energy use between Trinidad and Tobago and the rest of the target countries, with Trinidad and Tobago alone consuming 3.5 times the energy of all the other target countries, and 2.5 times as much as the rest of the CARICOM member states combined. This is further highlighted in Figure 5.2, which shows the substantially lower cost of energy in Trinidad and Tobago and the substantial drop in energy use per capita with increasing cost of electricity.

In the light of the ramping up of US natural gas export capacity, the conversion of energy systems from predominantly fuel oil-based systems to liquefied natural gas (LNG)-based systems is being proposed for some Caribbean countries (IDB 2013a). LNG has the advantage that it is cleaner than fuel oil plants, with LNG plants emitting less carbon dioxide (CO_2) per tonne. LNG also has considerable cost benefits compared with existing energy systems, with all-in costs estimated to be US$0.14/kWh. However, continuing advancements in recent years have resulted in several renewable energy technologies frequently being the most competitive form of new electricity generation option, often beating natural gas on levelised cost of energy. Given the large infrastructure changes needed to adapt to LNG-based energy systems, the economic cost and risk of conversion for some small islands are proving prohibitive – with one regional utility company recognising that conversion to natural gas is uneconomical and suggesting that renewable resources offer more environmental and economical benefits, as well as better market stability and energy security/resilience (Emera 2015).

Initiated in 2002 and approved in 2013, the goal of the CARICOM Regional Energy Policy is a fundamental transformation of the energy sector through the provision of indigenous, secure and sustainable supplies of energy (CARICOM 2013). This policy seeks to guide the Caribbean community in its pursuit of a sustainable energy sector and has a renewable energy (RE) target of an overall 47 per cent share in the region by 2027.

Table 5.2 Energy statistics for the selected countries in the Caribbean

	Grenada	Saint Lucia	Barbados	The Bahamas	Guyana	Jamaica	Trinidad and Tobago
Population	104,000	174,000	273,000	343,000	754,000	2,700,000	1,300,000
Energy (PJ/year)	4.2	5.6	21.3	33.1	41.8	136.4	848.1
Energy per capita (GJ/year)	40.4	32.2	78.0	96.5	55.4	50.5	652.4
GDP/capita (US$)	$7,500	$6,890	$15,035	$22,665	$3,739	$5,133	$16,614
Cost of electricity US$/kWh	$0.40/kWh	$0.38/kWh	$0.32/kWh	$0.26/kWh	$0.32/kWh	$0.36/kWh	$0.06/kWh
Electrification rate	99.5%	98.0%	100.0%	100.0%	66.0%	92.0%	99.0%

Source: IRENA 2012a, IRENA 2012b

In 2009, the CARICOM Secretariat commissioned the Caribbean Sustainable Energy Roadmap and Strategy (C-SERMS), designed to build on existing regional efforts and to provide CARICOM member states with joint regional sustainable energy targets and a common, coherent strategy for transitioning to sustainable energy systems (Worldwatch 2012).

Emerging from C-SERMS, the Worldwatch Institute's 2012 summary report for policy-makers provides an in-depth assessment of the region's energy sector, and notes that:

> *despite the strong potential for energy efficiency and renewable energy observed in all CARICOM member states, the development of sustainable energy systems will not occur organically, at least not to the extent or at the pace needed to rapidly harness their full socio-economic and environmental benefits. Regional and national governing bodies must be proactive in implementing policy frameworks that promote the investments needed to encourage energy efficiency improvements and allow renewable energy projects to take hold.*

Furthermore, according to this report:

> *no single policy mechanism can successfully transform a nation's entire energy sector. Instead, policy-makers must design and implement an appropriate policy mix that matches unique domestic conditions. International experience shows that countries that have successfully promoted renewable energy and energy efficiency score high on three essential building blocks:*
>
> 1. *A long-term vision that includes goals and targets;*
> 2. *Concrete policies and measures to achieve these goals and targets; and*
> 3. *Effective administrative processes and governance structures for implementing and revising these mechanisms.*
>
> *Establishing an official long-term vision for sustainable energy development that lays out clear goals and priorities and commits all government stakeholders to a common and cohesive strategic agenda represents a crucial component of effective sustainable energy planning. CARICOM has taken a significant step forward by finalizing its Energy Policy. In addition to this regional vision, all 15 CARICOM member states now have a national energy policy in place or in some stage of development, a significant improvement from when development of the CARICOM Energy Policy began a decade ago.*
>
> (Worldwatch 2012, 18–19)

5.2.2 Strategies of the selected countries

Various factors contribute to high energy and transport costs, diseconomies of scale and unfavourable power plant management protocols for the different Caribbean countries. The energy strategies and differences of each country are discussed in the following sections. Table 5.3 summarises the policy and regulation status of the countries targeted in this report.

Table 5.3 Current policy and regulation status of the energy sector in selected countries

	Policy status	Legislation status	Harmonisation of legislation with RE/SD	Policy target	Independent regulator	Economic incentives	Monitoring of implementation
The Bahamas	National Energy Policy 2013–2033, Action Plan every three years	Under review	Revised legislation expected to be	30% of electricity generated from RE by 2033	Utilities Regulation Competition Authority to assume responsibility for electricity sector	Some	Yes
Barbados	2012 Draft National Policy being revised	Revised legislation awaiting proclamation	Revised legislation expected to be	29% of electricity generated from RE by 2029	Fair Trading Commission	Many	Proposed
Grenada	2011 National Policy being revised	Under review	Revised legislation expected to be	20% of electricity generated from RE by 2020	None	No formal incentives	None
Guyana	1994–2004 National Policy expired, 2014–2018 Strategic Plan				Public Utilities Commission	Exist, but unknown*	Yes
Jamaica	2009–2030 National Policy	Under review	Revised legislation expected to be	20% of electricity generated from RE by 2030	Office of Utilities Regulation	Limited	Yes

(*continued*)

Table 5.3 Current policy and regulation status of the energy sector in selected countries (*continued*)

	Policy status	Legislation status	Harmonisation of legislation with RE/SD	Policy target	Independent regulator	Economic incentives	Monitoring of implementation
Saint Lucia	Sustainable Energy Plan 2001, 2010 National Policy	Under review	Revised legislation expected to be	30% of electricity generated from RE 2020	To be set up	Limited	Yes
Trinidad and Tobago	2011 National Climate Change Policy	Needs revision	No	5% of electricity generated from RE by 2020	Regulated Industries Commission	Limited	Yes

Source: Interviews with government energy ministries, unless marked by asterisk
www.map.ren21.net

The Bahamas

The Bahamas imports 99 per cent of its energy needs, mostly in the form of oil products. The two main electricity generators are the state-owned Bahamas Electricity Corporation (80 per cent of total electricity production) and the privately owned Grand Bahamas Power Corporation (20 per cent of total electricity production), and together they have a generating capacity of 137MW. Because of the archipelago geography of The Bahamas, its electricity system comprises 16 isolated grids, which leads to substantial diseconomies of scale. Except for Trinidad and Tobago, The Bahamas has the highest energy consumption per capita among the target countries.

The islands have attractive renewable energy potential, with strong wind resources and good solar and biomass resources. With reasonably easy access to deep waters off most of its islands, ocean thermal energy conversion (OTEC) could also provide a sizeable amount of energy (UNDP 2014). Responsibility for the energy sector falls under the Ministry of Environment and Housing, with regulatory responsibility soon to be assumed by the newly created Utilities Regulation and Competition Authority (URCA).

The nation has a moderate target of 30 per cent of its electricity to be generated from renewable energy by 2033; however, with no firm supporting policy, strengthening of the policy and regulatory framework is required. Of the seven countries examined, the policy environment is least conducive in The Bahamas, with no regulation existing for the interconnection of power generation. This makes it nearly impossible for independent power producers (IPPs) to feed into the existing grid. Neither are there any national energy efficiency standards or a national energy conservation effort; some estimates suggest as much as 27 per cent of electricity demand could be saved through efficiency measures alone (IDB 2013b).

Subsidies are of concern for transition towards a sustainable energy system, with The Bahamas giving away a sum equivalent to 1 percentage point of gross domestic product (GDP) in pre-tax subsidies to its petroleum and energy sectors, the second-highest such figure among Caribbean oil importers (*Bahamas Tribune* 2015). Such subsidies, if continued, along with the non-consideration of the external costs associated with fossil fuel use, places renewable energy technologies at a distinct economic disadvantage.

Barbados

With 1,000 barrels/day of oil extracted and sent to Trinidad for refining, Barbados is one of the few Caribbean islands with its own fossil fuel resources. This represents one-fifth of local demand. It also produces the equivalent of around 500 barrels of oil per day of natural gas for local consumption (see Figure 5.1). Barbados Light and Power (BL&P) is the sole provider of electricity on the island. BL&P is privately owned by Light and Power Holdings Ltd (LPH), which is also the majority shareholder in Dominica Electricity Services (DOMLEC) and an investor in St. Lucia Electricity Services Ltd (LUCELEC). Light and Power Holdings Ltd is majority owned by the Nova Scotia-based utility company, Emera. Emera is also the majority owner of the

Grand Bahama Power Corporation (see the Bahamas section). BL&P has an installed generation capacity of 235MW.

The Barbados government's Energy Division comprises an Administrative Unit, a Legal and Regulatory Unit, a Natural Resources Department, a Renewable Energy and Energy Conservation Unit and a Research and Planning Unit, and falls within the Prime Minister's Office. The Energy Division is currently overseeing a Public Sector Smart Energy programme funded by an Inter-American Development Bank (IDB) loan (US$17 million) and an EU grant (€5.8 million) (IDB 2012; GoB 2010). The division is also responsible for monitoring the island's local oil interests, both onshore and offshore, and is currently overseeing the island's 2015 offshore licensing campaign (GoB 2015). The 2012 Draft National Policy for Barbados is currently being revised. The independent Fair Trading Commission oversees regulation of electricity (Barbados FTC 2015).

Barbados has attractive wind, solar and biomass resources. Its solar resources have been technically exploited since the 1970s, because of a now well-established solar hot water heating industry – approximately 30 per cent of the island's homes have locally manufactured solar water heaters installed, with many of its hotels also making use of this technology. More recently, approximately 7.5MW of distributed solar photovoltaic (PV) systems were connected to the island's utility grid through BL&P's Renewable Energy Rider programme. Under this programme, all electricity exported to the grid receives a credit at 1.6 times the Fuel Clause Adjustment (a fuel surcharge), up to one-and-a-half times the customer's historical usage; above this, the customer is compensated at the rate of the Fuel Clause Adjustment (BREA 2014a). At the moment, IPPs have no legal standing; however, in 2015 the Electric Light and Power Act is set to make provisions for utility-scale IPPs.

The current total capacity limit for variable renewable energy onto the electricity grid is 20MW of distributed solar PV and 20MW of utility-scale solar PV. BL&P is planning the installation of an 8MW utility-scale solar PV plant in the north of the island during 2015 and, in a recent RE grid integration study, acknowledged that its electricity grid can accommodate up to 66MW of solar PV (45MW distributed and 20MW utility scale) and at least 15MW of wind energy capacity, with minimal mitigation measures (BL&P 2015). This is approaching half of the peak demand and signals that similar penetration rates across the whole of the Caribbean may be also possible.

The island has a strong lobbying group for renewable energy in the form of the Barbados Renewable Energy Association (BREA). Active since 2012, BREA has become a central voice for the use of renewable energy on the island, and serves the interests of the island's sustainable energy-focused companies, institutions and the general public (BREA 2014b).

The current policy target for the island is for 29 per cent of renewable energy generation by 2029; however, many key stakeholders within the energy sector recognise that this target is low. Signals from the country's BL&P utility company (Emera 2015), and presentations arranged by BREA together with the University of the West Indies (UWI), Cave Hill Campus (Hohmeyer 2014), suggest that transitioning towards 100 per cent renewable energy generation is an attainable target by 2050.

Throughout the Caribbean, the transport sector accounts for between one-third and one-half of primary energy use, and is dependent upon fossil fuels. Barbados is making strong progress towards the use of cleaner, more efficient vehicles. A local company, Megapower, has imported more than 100 electric vehicles to date, and, with many of its customers installing solar PV systems, provides a clear message that a clean transport sector is an economic possibility (Megapower 2015). The company is also exploring other Caribbean markets, including Grenada, Dominica, Saint Lucia and Antigua.

Grenada

As with elsewhere in the Caribbean, Grenada is almost wholly dependent on imported oil products, which provide 93 per cent of its overall energy supply. The remaining 7 per cent is provided largely by solid biomass (see Figure 5.1). Generation, transmission and distribution of electricity on the main islands are provided by the private/public-owned Grenada Electricity Services Ltd (GRENLEC). The utility has an installed capacity of about 50MW.

The island has an electricity access rate approaching 100 per cent; however, high energy costs continue to restrict the ability of homeowners and businesses to access reasonably priced electricity, which is urgently required to encourage sustainable economic growth.

Grenada has good geothermal, solar, wind and some hydropower potential. It aims to produce 20 per cent of all its electricity and transportation consumption from renewable energy sources by 2020 and 100 per cent by 2030. The National Energy Policy of Grenada was approved in June 2011 and governmental responsibility for energy lies with the Ministry of Finance, Planning, Economy, Energy and Cooperatives. Grenada has been working closely with the International Renewable Energy Agency (IRENA) and 2012 saw the production of a renewables readiness assessment (IRENA 2012b), which outlines key recommendations to foster the deployment and sustainable use of renewable energy resources in the country. Some of the recommendations include the setting up of an energy regulator and provision for the review of its existing interconnection policy to promote business models that can increase the deployment of renewables.

Through the assessments that have already been carried out, including the SE4ALL rapid assessment and gap analysis in partnership with the World Bank and United Nations (SE4ALL 2014), Grenada has recognised that it must strengthen a number of areas, including its institutional framework; sustainable energy education among technicians and engineers; awareness among the general public; and the provision of reasonably priced funding for sustainable energy investments in the public and private sectors.

Guyana

Guyana does have some fossil fuel reserves; however, these have never been tapped at a commercial level. Imported oil products account for just over half of its primary energy use, with combustion of solid biomass providing much of the remainder. The

state-owned Guyana Power and Light Inc. (GP&L) is the primary transmitter and distributor of electricity, and also generates approximately half of the electricity in the country. The second largest generator is the Guyana Sugar Corporation, which sells its excess electricity to GP&L. National energy statistics are difficult to measure, given that the majority of large and medium-sized firms rely on self-generation of electricity, and that the country's vast hinterland and rural communities are supplied from small-scale private energy companies. There is a stark contrast in terms of electrification rate: first between Guyana and much of the Caribbean, with approximately 60 per cent of the population having access to electricity compared with between 95 and 100 per cent in most other countries (Haiti being the main exception, with just 38.5 per cent); and then within Guyana, with the main coastal populations approaching 90 per cent with access to electricity compared with around 20 per cent in the more remote parts of the country. This low penetration rate lends itself to an expected rise in energy demand in the future.

Guyana's National Low Carbon Development Strategy was approved in May 2010, with responsibility for energy sector development overseen by the Guyana Energy Agency (GEA) (GEA 2015a). Energy sector regulation is controlled by the Public Utilities Commission (PUC).

Guyana has significant hydropower potential, with studies indicating a potential capacity of 4.5GW and with 11 of the 65 sites investigated capable of providing more than 100MW of hydropower. However, no large-scale sites have yet been exploited, with the planned Amaila Falls project remaining under review (GEA 2015b; *The Economist* 2013). Solar is seen to be a viable option to bring cheaper electricity to Guyana's hinterland. However, the wind resource is low in the hinterland and efforts here are focused more on its coastal region.

There are a number of different agencies involved in Guyana's energy policy formulation and execution (REEP 2012).

The government, through the Office of the President, is responsible for the development of energy policy and national planning. Within this structure, the quasi-government agency – the GEA – is tasked with 'ensuring the rational and efficient use of imported petroleum-based energy sources, while encouraging, where economically feasible and environmentally acceptable, increased utilization of indigenous new and renewable sources of energy'. Part of the GEA's mandate is to develop conservation programmes, facilitate greater adoption of renewable energy technologies to reduce greenhouse gas emissions, and reduce the effects of climate change through the creation and adoption of appropriate mitigation measures.

The Office of the President provides guidance in the areas of environment and climate change at the national policy level, while the Office of the Prime Minister (OPM) also has policy-making and regulatory responsibilities. The issuance of licenses to public utilities and independent power producers, approval of developmental and expansion plans, the formulation of standards of service for GP&L, the national electric utility, and the electrification of the hinterland and other rural areas, all fall within the purview of the OPM.

The PUC is the energy regulator and has responsibility for the determination and setting of tariffs, as well as monitoring and enforcement of standards and targets set by the OPM.

Laws that directly impact the functioning of Guyana's energy sector are:

- Hydro-Electric Power Act (1956);
- Guyana Forestry Commission Act (1979);
- Petroleum (Exploration and Production) Act (1986);
- Environmental Protection Act (1996);
- Energy Agency Act (1997);
- Public Utilities Commission Act (1999);
- Electricity Sector Reform Act (1999);
- Energy Sector (Harmonisation) Act (2002).

The existing energy policy outlines the goals for 2004 as:

- providing a stable, reliable and economic supply of energy;
- reducing dependency on imported fuels;
- promoting, where possible, the increased utilisation of domestic resources; and
- ensuring energy is used in an environmentally sound and sustainable manner.

This policy is in need of updating if it is to be in alignment with recent developments in the energy industry, i.e. the economic viability of solar and wind technologies, and other pressing concerns such as energy security and the state of the national economy. The last material changes to the energy policy occurred in 1999, when the Electricity Sector Reform Act was passed.

There is significant overlapping and layering of responsibility among the various government energy agencies. Regulatory functions appear to be fragmented and scattered across several agencies. One example of this is the existence of a pre-determined rate-setting formula in the GP&L licence, as administered by the OPM, and in the Electricity Sector Reform Act, although the PUC is vested with the authority to determine and approve public suppliers' tariffs. Such inefficient use of scarce human and capital resources will invariably lead to ineffective decisions and conflicting practices. Therefore, the PUC and the Guyana Energy Agency do not appear to be afforded the level of autonomy that well-functioning and transparent agencies of this nature require.

Jamaica

The energy sector in Jamaica is overshadowed by the fact that the economic cost of its energy imports exceeds the value of total Jamaican exports. As indicated in Figure 5.1, most of Jamaica's energy needs, about 83 per cent, are imported in the form of

crude oil, coal and oil products. Solid biomass accounts for the remaining 16 per cent of primary energy supply. Hydropower and wind power currently represent 1 per cent of primary energy use.

The bauxite industry is the largest end user of energy, consuming approximately 37 per cent of total energy, followed by the electricity sector, which consumes about 25 per cent of primary energy. The island's transport sector consumes around 20 per cent of its primary energy use, while the sugar industry uses approximately 12 per cent. While the bauxite industry is very energy intensive, it makes a significant contribution to the balance of payments, generating much-needed foreign revenue through exports (IDB 2013c).

The Ministry of Science, Technology, Energy and Mining has overall responsibility for the formulation and review of energy policy, including improvement of national energy efficiency and conservation, and increasing the percentage of electricity generation from renewable sources, thereby reducing dependence on imported fuels and increasing Jamaica's energy security. The Energy Division within the ministry implements policy and monitors the functioning of the energy sector. It works with the Petroleum Corporation of Jamaica (PCJ) and the Jamaica Public Service Company (JPSCo) (Government of Jamaica Ministry of Science, Technology, Energy and Mining 2015). With a generation capacity of 820MW, JPSCo has virtually all of the island's electricity-generating capacity.

Jamaica has wind, biomass and hydro potential, and extensive solar potential. It already has more than ten years of utility-scale wind power experience thanks to the 20MW capacity Wigton Wind Farm (Wigton Wind Farm Ltd 2011). This wind farm was expanded to 38MW in 2010, with another 24MW of capacity due to be installed in the near future. The Wigton Wind Farm project is the only large-scale wind farm in the CARICOM region and provides valuable experience of wind farm development and operation.

Saint Lucia

Saint Lucia has no known petroleum reserves and receives about 98 per cent of its overall energy from imported oil products; the remaining share comes from combustible solid biomass. St. Lucia Electricity Services Limited (LUCELEC) is the sole utility company generating, transmitting and distributing electricity. It holds the sole licence until 2045, with the exception of customer self-generation.

Government oversight of energy lies with the Energy Policy Advisory Committee within the Ministry of Sustainable Development, Energy, Science and Technology. The Saint Lucia National Energy Policy was approved in January 2010. Regulation of the energy sector is currently under review, responsibility for which is with the Ministry of Public Utilities. An independent regulator is in the process of being formed. The policy target for the island is for 30 per cent of its electricity to be generated from renewable sources by 2020.

The island has a good mix of renewable energy, including solar, wind, hydro, biomass and geothermal resources. The geothermal potential, in particular, is said to be high.

Although previous exploration experiences during the 1970s yielded no technical potential, the island is revisiting its prospects for geothermal sources. Other islands, including Dominica, Grenada, Montserrat, St Kitts and Nevis, and St Vincent and the Grenadines, are also exploring their extremely high geothermal potential, which, if successful, could dramatically alter the energy balance of these islands and the region as a whole. With assistance from the European Union, Dominica in particular is making good progress in exploiting its geothermal resource, with exploration wells showing proven capacity and bidding on production plant development expected soon (EU 2015). The possibility of regional grid interconnections to enable renewable energy exports is also being explored (Worldwatch 2012).

Trinidad and Tobago

Trinidad and Tobago's energy sector is dominated by oil and gas production, and the twin island state is among the five largest exporters of LNG in the world. Until the large-scale development of shale gas in the United States, Trinidad and Tobago supplied 60 per cent of American LNG imports. Today natural gas accounts for almost 90 per cent of the country's energy sector. The largest companies operating in the sector are BP Trinidad and Tobago, British Gas and EOG Resources Trinidad. Together they account for about 95 per cent of production. The majority of gas production, 57 per cent, is exported in the form of LNG, with much of the rest used domestically in the petrochemical industry (28 per cent). The electricity sector accounts for only 8 per cent of its natural gas production.

In addition to natural gas, Trinidad and Tobago produces approximately 80,000 barrels of oil per day (2012) of which 20 per cent is consumed domestically, inclusive of the transportation sector.

Through the development of its petrochemical sector (it is the world's leading exporter of ammonia and methanol), Trinidad and Tobago has shown an ability to diversify its oil and gas sector. However, the non-energy sector is relatively underdeveloped, attracting little investment, and is heavily dependent on government subsidies and transfers. Compared with other Caribbean nations, Trinidad's tourism and agriculture sectors are small. Oil and gas reserves are currently predicted to run out between 2025 and 2030, and so there is a growing sense of urgency to diversify its economic sector.

Trinidad and Tobago Electricity Commission is the state-owned utility company and dominates the electricity sector. It is responsible for operation and maintenance of all of the country's transmission and distribution lines, and is also the sole power generator on the island of Tobago. Total generation capacity stands at 1,761MW (IDB 2013d).

The Ministry of Energy and Energy Affairs and the Ministry of Public Utilities have oversight of the country's energy production and generation. There is no existing national renewable energy plan; however, the 'Framework for Development of a Renewable Energy Policy for Trinidad and Tobago' has been in draft since 2011. The country has a 2011 National Climate Change Policy that speaks to 5 per cent of peak demand being generated from renewable energy by 2020. The Regulated Industries Commission is the independent regulator of the electricity sector.

Energy in Trinidad and Tobago is highly subsidised, and this has resulted in the lowest diesel fuel prices, and commercial and industrial electricity prices, in most of the Americas. The island has promising wind, solar and bioenergy potential; however, given the extremely low cost of conventional energy, renewable energy is placed at a competitive disadvantage (T&T MoE 2014).

5.3 Scan of external environment determining emerging trends and risks

Given the fact that modern renewable energy technologies (excluding combustion of solid biomass) currently make up just 0.09 per cent of the primary energy share of the selected countries, and that all of these technologies are already economically feasible in many parts of the Caribbean, there is no shortage of a market for their use. This section provides an assessment of the various sustainable energy technologies that have potential for deployment in the Caribbean region, and discusses emerging trends and risks for their use, from both an international and a regional perspective. It also examines potential game changers, such as advancements in energy storage (battery technology) and energy generation (e.g. marine energy/solar PV/floating wind turbines).

5.3.1 Energy efficiency and energy conservation

In tandem with renewable energy technologies, energy efficiency and energy conservation measures can be deployed across all economic sectors to reduce energy demand, and are often both the cheapest and the fastest way to lessen the economic, social and environmental costs of energy. It is for this reason that energy efficiency and conservation are discussed first.

Energy efficiency is crucial because of its compounding effects: when a user demands one less unit of energy because of efficiency measures, the system typically saves much more than one unit of produced energy, because of avoided losses during generation, transmission and distribution. As a result, efficiency improvements can amplify the benefits of developing utility-scale renewable energy by increasing the impact of added renewable power capacity.

Opportunities for efficiency measures at the building and household level should be harnessed for energy and cost savings. Buildings themselves can be made significantly more efficient through proper insulation, white roofing and smart architecture/landscaping. In-home products such as household appliances continue to consume comparatively large volumes of electricity. Their inefficiency is exacerbated in the Caribbean by the prevalence of outdated equipment and a lack of strong efficiency standards for new appliances, although progress is being made across the Caribbean thanks to work by the CARICOM Regional Organisation for Standards and Quality (CROSQ 2015) and the OAS (2015) and, for example, with the formation of the Barbados Energy Performance Label by the Barbados National Standards Institute (BNSI 2015). As regional economic development increases, the corresponding growth in energy demand from electrical appliances and other household products, such as air conditioning systems, will need to be managed through efficiency standards.

Economic sectors that should be targeted for energy efficiency measures and technologies are those that (1) account for a large share of a member state's energy consumption; (2) are highly energy intensive or inefficient; or (3) are priority components central to the national economy. Across the CARICOM region, such sectors include electricity generation, electricity transmission, hotels and tourism, mining, the residential sector and government. Energy efficiency in the transport sector must also be addressed through specifically targeted measures that differ from those that can be deployed in other sectors. The transport sector is responsible for between one-third and one-half of fossil fuel use throughout the Caribbean, and there are a number of policy initiatives that could be explored in order to encourage more efficient use of fuel in this sector. These include the introduction and enforcement of stricter tailpipe emission targets, better traffic management initiatives to reduce congestion at peak hours, support for the introduction of electric vehicles (reduction/removal of import duties and road tax and investment in support infrastructure) and overhaul of public transport sector.

5.3.2 Solar

Thanks to their location and climatic conditions, countries throughout the Caribbean possess excellent solar energy potential and opportunities to use various solar technologies for power generation, heating and cooling. For example, a solar PV system can expect to yield twice the amount of electricity that a similar system installed in Germany would generate, yet Germany has the world's highest installed solar PV rate per capita.

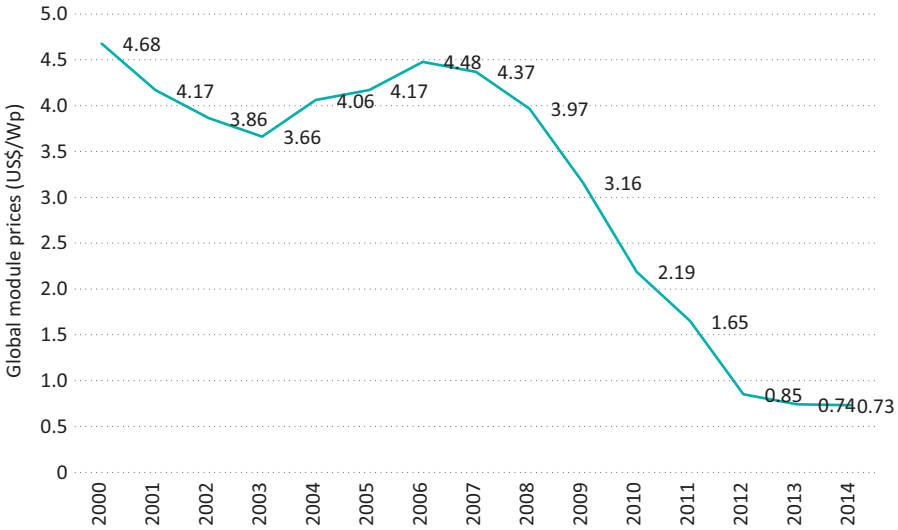
The cost of solar PV has fallen significantly in recent years (see Figure 5.3), making solar PV cost-competitive with fossil fuels for many Caribbean islands. The Fraunhofer study on the current and future cost of solar PV predicts that:

> *Solar power will soon be the cheapest form of electricity in many regions of the world. Even in conservative scenarios and assuming no major technological breakthroughs, an end to cost reduction is not in sight. Depending on annual sunshine, power cost of 4–6 US¢/kWh are expected by 2025, reaching 2–4 US¢/kWh by 2050 (conservative estimate).*
>
> (Fraunhofer 2015, 5)

Grid parity occurs when an alternative energy source can generate power at a levelised cost of electricity (LCOE) that is equal to or less than the price of purchasing power from the electricity grid. Essentially, grid parity for solar PV use in much of the Caribbean has been reached and prices are predicted to decrease well below grid parity in the coming years. This has been recognised by Caribbean utility companies. For example, BL&P is finalising plans for the installation of 8MW of centralised solar PV by early 2016.

With the growing interest in solar PV, the use of solar thermal technologies for hot water heating should not be forgotten. The solar water heating industry has experienced success in many parts of the Caribbean, in particular Barbados, where Barbadians have been saving millions of dollars annually by using locally manufactured systems.

Figure 5.3 Global solar PV module prices 2000–2014



Source: pvXchange 2014

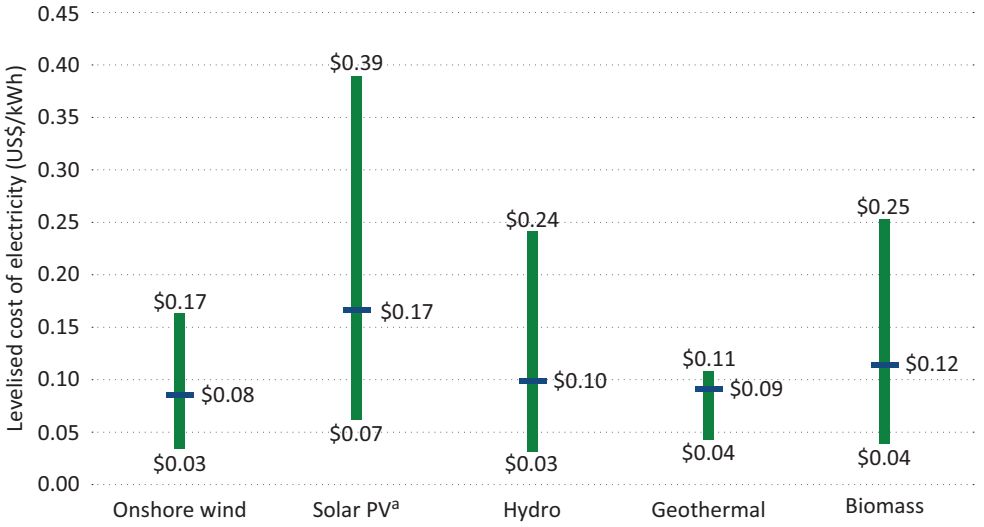
Solar thermal is often the most cost-effective option for providing process heat/cooling in the tourism and agro-processing sectors, but is not often explored.

5.3.3 Wind

The wind resource on exposed Atlantic coastlines across the Caribbean is comparable with the very best offshore locations in Europe. There is strong potential for development of this vastly under utilised resource. Many experts consider wind the most viable renewable energy technology for rapid expansion in the region over the next two decades (Caribbean Renewable Energy Development Programme and Deutsche Gesellschaft für Internationale Zusammenarbeit 2011). The main reason for this is that, resources permitting, it is one of the cheapest options ($0.08/kWh) for electricity generation worldwide (see Figure 5.4), even when compared with traditional technologies such as combined cycle gas turbines ($0.09/kWh), coal ($0.10/kWh) and nuclear ($0.09/kWh). Currently, however, few CARICOM countries have developed utility-scale wind infrastructure. The exceptions are Jamaica, which now has more than 40MW of installed wind capacity (see Jamaica section), and St Kitts and Nevis, which has 2MW installed.

Given that many Caribbean islands have a high population density, the possibility of offshore wind has been raised. However, steep drop-offs within a relatively short distance from the shore means that offshore wind will probably be limited to offshore floating wind turbines, as the capital cost of seabed-anchored turbines is prohibitive. These turbines are currently in their prototype stage in European and North American markets, and are not expected to be available to the Caribbean market for some 10 to 15 years. During this time, onshore wind turbines could have saved the region extensive amounts of foreign exchange.

Figure 5.4 Typical levelised costs of electricity ranges and weighted averages by technology for Central America and the Caribbean



***Note:** Revised for Caribbean from GTM Research 2015
Source: IRENA 2014

Financial and regulatory environments will be key to reducing costs in the future. The cost of hardware sourced from global markets will decrease irrespective of local conditions. However, inadequate regulatory regimes may increase the cost of power by up to 50 per cent through the higher cost of finance. This may even overshadow the effect of better local wind resources.

5.3.4 Hydro

Large hydropower comprises the majority of currently available renewable power generation within CARICOM. However, most sites on the region's islands have already been developed (perhaps with the exception of Haiti). This means that future development of large-scale hydropower facilities will be focused on mainland countries, such as the 165MW Amalia Falls project in Guyana (IDB 2010). Although large-scale hydropower is location specific (mainly Guyana and Suriname), it does have substantial potential, presenting opportunities to broaden and interconnect regional energy markets.

Small hydro plants, typically classified as generating less than 10MW of electricity, have significant environmental and social advantages over large-scale hydro, but development feasibility (especially for run-of-the-river systems) requires specific site characteristics that preclude its use in several small-island CARICOM member states. Elsewhere, the potential for small, sustainable hydro deployment is significant, particularly for providing electricity access to remote, currently underserviced populations, e.g. in the hinterland of mainland countries, as well as Haiti (Worldwatch 2012).

5.3.5 Modern biomass (including bagasse and biogas)

Biomass has a significant advantage over other renewable energy resources in that it is easily storable. Belize is a regional leader in the use of bioenergy as a base load energy source. Many CARICOM member states, particularly those on the mainland and the larger island states, have good biomass potential. Waste-to-energy technologies are considered to be thermal power plants in that they raise steam to drive a turbine, which then drives an electrical generator. These types of plants can have characteristics that make it difficult for them to respond to variable changes in a utilities power curve – for example, if there are large numbers of intermittent power plants such as wind and solar. Thermal power plants also have environmental and social side effects that could lower their suitability for modern energy systems. Waste-to-energy technologies have drawn some attention throughout the region for their ability to solve the waste disposal problem. Their viability is restricted in those states with limited waste collection capacity or comparatively small populations, as these states do not generate the volumes of waste necessary to make waste-to-energy plants economically viable. What should also be considered when discussing waste-to-energy is the potential assistance it can offer local agriculture sectors. Sugarcane farmers across the region have been suffering in recent times, given the low price of sugar on the international market. The possibility of growing high-fibre sugarcane as an energy crop holds some attraction to the agriculture sector.

Other forms of modern biomass include biodigesters, which anaerobically digest organic matter – the output, after some gas scrubbing, being gaseous biomethane and a valuable fertiliser. Biodigesters have been used for decades in many parts of the world and offer a way of effectively treating animal and human sewage, as well as waste from the agro-processing industry (breweries and distilleries). Energy crops, such as napier grass and sugarcane, can also be used, offering a cleaner alternative to cogeneration that ensures the vital nutrients are returned to the ground rather than being combusted.

5.3.6 Geothermal

Many CARICOM member states, particularly the islands making up the volcanic arc of the Lesser Antilles, have significant untapped geothermal resources. Development of this resource in Dominica, Grenada, Montserrat, Nevis, Saint Lucia and St Vincent and the Grenadines is currently being explored and could dramatically alter the energy balance of these islands – and even the Caribbean as a whole if regional grid interconnections are developed to enable renewable energy exports. Currently, no CARICOM state has developed geothermal power (Guadeloupe has operated geothermal plants since 1986 – now up to 15MW, with plans for more capacity). The downside to geothermal (see Figure 5.4) is that exploration of suitable resources has some degree of financial risk. Nevertheless, given the potential cheap levelised cost of electricity, exploratory drilling and preliminary investigations are under way in several islands.

5.3.7 Marine energy

Energy technologies including wave, seawater air conditioning and OTEC have been identified as a priority area under the Small Island Developing States Sustainable Energy

Initiative (SIDS DOCK). These technologies offer significant potential throughout the region, presenting opportunities including electrical power generation and centralised cooling (for hotels, business districts and cold-water agriculture). However, marine energy technologies remain in the developmental phase and still have prohibitively high costs that limit their deployment in the short term. CARICOM member states are currently taking steps to advance pilot projects for OTEC, although the technology's long-term potential in the region is restricted by factors including uncertain technology development and project scale. An OTEC pilot project is currently under way on the island of Martinique, with plans for a 10.7MW floating OTEC plant. Elsewhere, Barbados is set to explore its resource potential for several marine energy technologies including wave, offshore wind and OTEC.

5.3.8 Cost for utility-scale new generation

The cost of renewable energy technologies has dropped in recent years, with most of the technologies passing grid parity – assuming appropriate resource potential. Figure 5.4 shows the levelised cost of energy (the total lifetime costs incurred by a power plant divided by the amount of energy it is expected to produce) for different types of renewable energy technologies. Except in the case of solar PV, the data is for Central America and the Caribbean combined; however, it does give an idea of the economic viability of all renewable energy resources for the entire Caribbean. The fact that the total lifetime costs incurred by any renewable energy technology might be expected to be higher for Caribbean islands would probably be balanced by the fact that the resource is so much better than in other parts of the world (especially for wind and solar).

5.3.9 Importance of storage

Grid and storage solutions have strong potential to transform CARICOM's existing energy sector. Across the region, existing grid infrastructure is largely out of date and often insufficient to meet the population's current and growing energy needs. This is evidenced by the region's high technical losses and, in select member states, a lack of reliable electricity access.

Without further development, existing grid networks will be unable to successfully address the technical challenges associated with the increased share of renewable energy envisioned by CARICOM and its member states. New grid infrastructure will be necessary to manage variability and to integrate complementary renewable energy sources into transmission and distribution networks to supply reliable power. 'Smart grid' advancements have the potential to manage demand by shifting loads to off-peak hours and by better utilising domestic renewable energy resources. At the household level, the deployment of smart meters, combined with appropriate policy mechanisms, would allow customers to generate their own renewable power and sell excess electricity back to the grid.

Electricity storage has the potential to play an increasingly important role, as greater shares of variable renewables are integrated into grid networks. Storage solutions are currently being assessed in a number of member states including Antigua and

Barbuda, where policy-makers are looking into pumped storage hydropower as a component of wind development.

The development of inter country infrastructure to enable some degree of electrical integration and/or regional energy trade could be a potential game changer for CARICOM's power sector. Already, some CARICOM member states use submarine interconnection cables to link individual islands, and a number of preliminary studies have been conducted that together confirm the feasibility and assess the implications of electricity interconnection in various parts of the Caribbean.

5.4 Analysis of key challenges

The Caribbean is currently standing on the threshold of a new energy future, one that can bring energy independence, higher-skilled jobs, clean water and air, liveable cities and improved health, and also help in the global push to avert the worst impacts of climate change. High existing energy costs and excellent renewable energy resources provide an opportunity for the region to quickly become an example to the rest of the world. Renewable energy technologies are now economically viable across much of the region, and momentum is gathering in the push to make use of them. However, there are a number of hurdles still to be negotiated. This section provides feedback from a survey of key regional energy stakeholders including governments, development partners, universities, utilities and businesses. A total of 31 stakeholders responded to the survey, all with substantial experience within their sector. We first present the thoughts of these stakeholders regarding the predicted and possible energy mix in 2050, before discussing perceived barriers to a transition towards sustainable energy systems.

5.4.1 View of the Caribbean energy sector in 2050 by regional stakeholders

The survey carried out for this work was seen as an opportunity to poll regional energy stakeholders on their views regarding the predicted energy mix of the Caribbean energy sector in 2050 versus what they feel could be possible.

Figure 5.5 reveals the difference between these two alternative scenarios, with experts appearing confident of a cleaner, more sustainable energy landscape than is predicted. Figures 5.6 and 5.7 breakdown the predicted and possible energy share by sector, and reveal that opinion is often divided among the stakeholders as to which technologies will prevail. In fact, even among survey participants from within each sector, opinions on technology choice varied quite substantially – some experts predict that geothermal will form a substantial share of the energy mix, while others opt for OTEC, wind energy or natural gas. The one technology almost all stakeholders agree will play a significant role is solar PV. The reason for the uncertainty between the different technologies is the thinking that a non-intermittent, dispatchable source of energy will be needed to provide power when the wind is not blowing or the sun is not shining (either from some form of fuel or from energy storage).

Respondents were generally hesitant to ascribe percentage compositions of the various technologies for a future energy mix. What was clear, however, was that

Figure 5.5 Predicted and possible energy sector breakdown in 2050 according to Caribbean energy sector actors

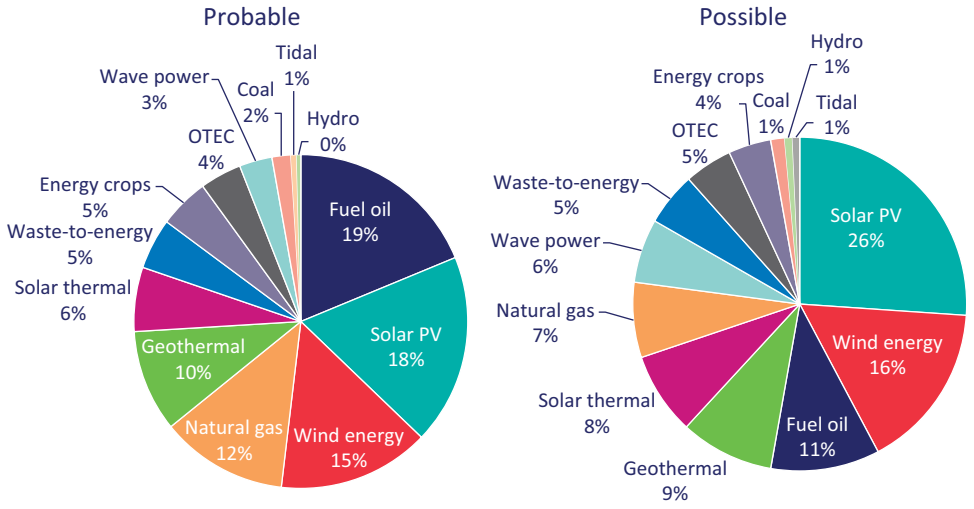


Figure 5.6 Probable energy sector breakdown in 2050 according to different Caribbean energy sector actors

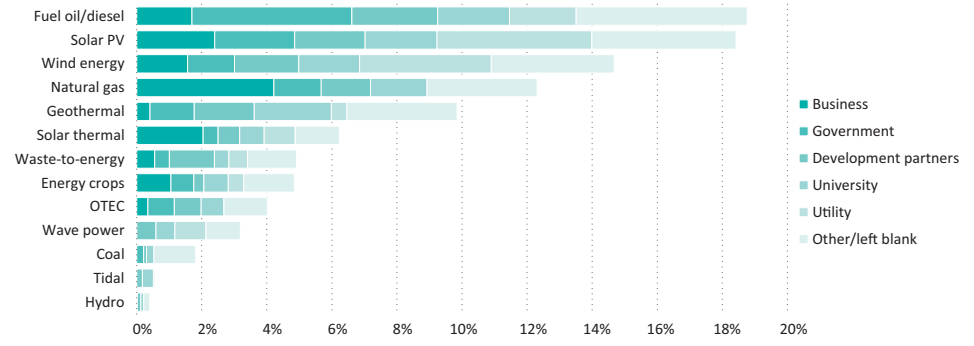
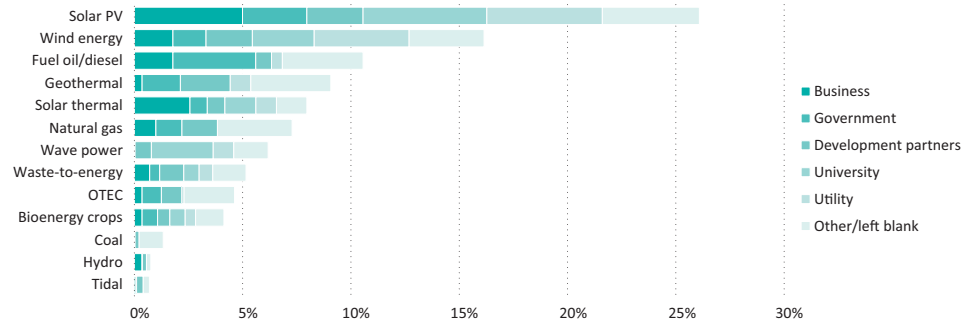


Figure 5.7 Possible energy sector breakdown in 2050 according to different Caribbean energy sector actors



all territories envisage a significant role for wind, solar PV and waste-to-energy. Comparatively, the waste-to-energy capacity is envisioned to be considerably less than that for wind and solar PV, the notable exception being Barbados. The Government of Barbados has entered into an agreement with Cahill Energy to develop a 40MW waste-to-energy plasma gasification plant by 2018.

Respondents from territories with geothermal resources (Grenada and Saint Lucia) suggested that by 2050 they would expect, both in their personal view and in reality, to have at least 60 per cent of the country's energy requirements being provided by geothermal sources. There was also the suggestion that, as is the plan for Dominica, neighbouring islands could benefit from interconnection of the geothermal output.

OTEC and tidal power were generally considered to be emerging technologies and, although they may appear technically feasible for the Caribbean, they still need to be proved commercially, so it is not expected that their uptake will be significant in the short-to-mid term.

5.4.2 Stakeholder analysis

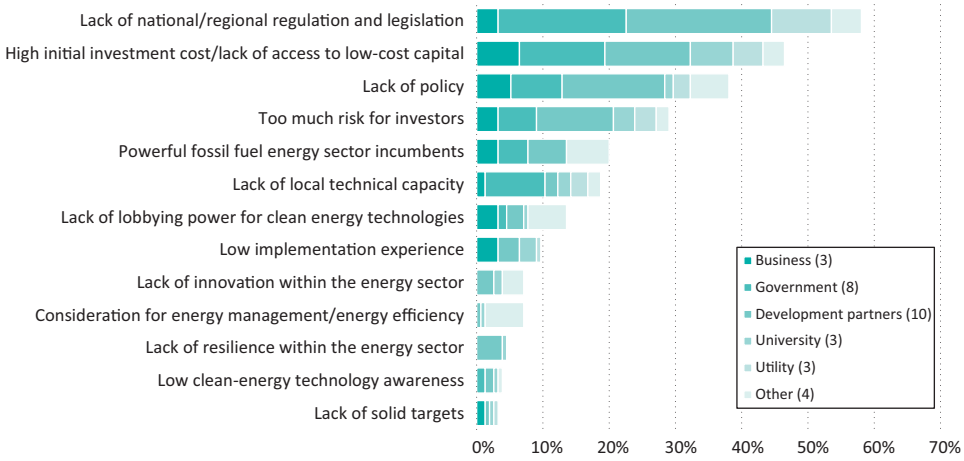
Most interview respondents found some difficulty in assigning a scaled impact to the various stakeholders; however, they unanimously considered the government and the incumbent utility to be the primary stakeholders and agreed that the government should be the principal proponent of a country's transition to a sustainable renewable energy sector. Other stakeholders believed to have significant impact on the development of sustainable energy are consumer bodies and associations, the utility regulator, and regional developmental bodies such as the Caribbean Development Bank and CARICOM. The local and international private sectors were also considered to be integral stakeholders.

The general public, academia, environmental agencies and standards institutions were identified as groups that needed to be encouraged to play a more active and strategic role in the development of a sustainable energy sector. It is thought that energy sector innovation may be best achieved through synergies between academia and the local private sector (finance institutions and entrepreneurs) – see, for example, the EU-funded CAP4INNO project (CAP4INNO 2013).

5.4.3 Perceived barriers to sustainable energy systems

Figure 5.8 lists the perceived barriers to sustainable energy systems, and the opinions of those surveyed as to which barriers require the most attention. A lack of national/regional regulation and legislation is noted as being a clear impediment to future energy sector development. None of the target countries have clear regulation or legislation for renewable energy technologies (as seen earlier in Table 5.3). It is apparent that a lot of the listed barriers are related: a lack of legislation and regulation, as well as no clear, definitive and unambiguous national energy policy, means that initial investment cost is high and the risk to the investor is great. It is telling that government stakeholders acknowledged a lack of local technical capacity and,

Figure 5.8 Perceived barriers for transition to a sustainable energy system from regional energy stakeholders



given that expertise in energy divisions around the region is stretched, this barrier connects directly to the lack of policy and regulation. Development partners noted that there is development funding available to de-risk and provide help for upfront costs (grants, concessional loans etc.) (CDB 2013). Political leadership and a lack of qualified energy experts in energy units and institutions in the region are seen to be major impediments to effectively accessing this funding. The results of this part of the survey mirror those of a similar survey conducted in April 2014 by the Reiner Lemoine Institut (Energypedia 2014).

A notable result of this part of the survey was the impact that powerful fossil fuel incumbents have on the energy sector, with respondents observing that 'Along with powerful fossil fuel energy sector incumbents [there] is a lack of transparency, and in some cases outright corruption in government' and 'A significant risk comes from the lack of real political leadership and the willingness to organize systematic and transparent processes that produce optimal outcomes'.

5.4.4 Vulnerability of energy infrastructure

Scientists have predicted that by 2100 an additional 20–60cm rise in sea level could be realised, depending on the world's actualised emissions trajectory and the interplay of thermal expansion and glacier ice dynamics (UNEP/GRID-Arendal 2007).

In any particular coastal region, as the Caribbean can be described, sea-level rise is governed not only by the dynamics of the global ocean, but also by the particular physical forces at work in that region itself.

Even without changes in frequency or intensity of storms, rising sea levels will lead to greater storm surges, and therefore greater risk to existing infrastructure (including saltwater poisoning of agricultural land). Scientific assessments from the US Global Change Research Program suggest that tropical storm intensity, not frequency, is likely to increase over the coming decades (USGCRP 2010).

The other major component of the potential impacts of sea-level rise and climate variability and change on energy infrastructure is the intrinsic vulnerability of the existing infrastructure. Infrastructure that is often situated in coastal areas is invariably vulnerable to storms, erosion, temperature extremes and other aspects of the physical climate system. Some of this vulnerability comes simply from location. The Caribbean islands as a whole, because of their size, can be considered coastal, and in many instances energy-generation infrastructure is located along sheltered western coastlines, with the transmission and distribution networks being predominantly overhead. These are clearly vulnerable to the effects of tropical storms and the rising sea level of the Atlantic Ocean and the Caribbean Sea.

Many Caribbean electric utility operators recognise this, and have operational policies in place to address such stressors. The immense difficulty in projecting climate variability and sea-level rise on a regional scale makes the choice of additional mitigation procedures that much more complex.

Burkett (2011) identifies six primary drivers of vulnerability for coastal energy infrastructure:

- increased ocean and atmospheric temperature;
- changes in precipitation pattern and runoff;
- sea-level rise;
- more intense storms;
- changes in wave regimes; and
- increased dissolved CO_2 and ocean acidity.

This list of physical drivers of vulnerability recognises that changes in the ocean environment, the near-shore terrestrial environment and the climate system itself have potentially important implications for energy infrastructure. The delivery of energy services is a multisectoral phenomenon, and thus considerations of the linked vulnerabilities of major infrastructures should be part of an analysis of potential adaptation options.

5.4.5 Challenges to the utilities

Utilities around the region have a number of challenges to their future operation. One of the biggest challenges is that some utilities are facing declining loads. Owing to the economic downturn and more wealthy customers opting to switch to self-generation energy options (including solar PV systems with battery), some utilities have found that their annual energy production has declined year on year – in some cases for the first time ever. A majority of this is from customers connecting small, distributed renewable energy systems (predominantly solar PV) to the grid. In Barbados, the connection of 7.5MW of solar PV to the BL&P grid has meant a 1.5 per cent decline in production of electricity from traditional fossil fuel sources since 2010. This alone has little impact on BL&P's revenue, as the electricity generated from solar PV offsets the avoided cost of fossil fuel generation.

However, the worldwide drop in solar module prices and batteries has allowed those customers who can afford it to disconnect completely from the utility grid – a phenomenon known as 'grid defection' (RMI 2014). This is of more concern to utilities, as these are normally their larger customers, and raises the threat of their utility grid becoming fractured.

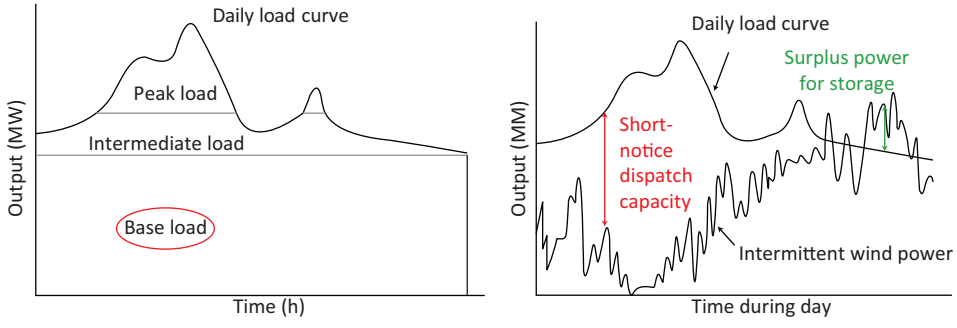
Intermittent renewable energy sources such as wind and solar are plentiful, and wind turbines and solar PV systems are two of the cheapest forms of renewable energy generation available today. However, they are intermittent in nature, meaning that they will have to fit within energy systems designed for base load operation, with peaking demand to meet the daily load curve (see Figure 5.9). In order to achieve this, some form of energy storage, or power plant with short-notice dispatch capacity, will be required. Most islands in the Caribbean use low-speed generators, which are able to provide short-notice dispatch; however, storage, such as batteries or hydro-pump storage would be a new addition to their infrastructure. This would require careful examination of existing infrastructure and the creation of completely new control strategies, able to balance the load demand of their customers with the varying power provided by wind and solar sources. In Barbados, BL&P has taken the first step towards higher penetration of renewables with the publication of its integrated resource plan in 2012 (BL&P 2012) and, more recently, the publication of its wind and solar integration study (Emera 2015).

Other challenges to regional utilities include low implementation experience in renewable energy technologies, the risk of stranded assets (whereby assets become obsolete before their lifetime) and unclear signals from governments with regard to energy policy and the regulatory/legislation environment, as evidenced by the utility responses to the survey performed for this study (see Figure 5.8).

5.4.6 Challenges to governments

To date, all 15 CARICOM member states have adopted a national energy policy or have a document in advanced stages of development. National policy-makers across the region have set domestic targets to promote renewable energy use. Many member

Figure 5.9 Tradition power plant operation (left), and power plant operation with intermittent power source (right)



Source: Hohmeyer 2014

states have already taken the lead in developing and implementing domestic policy mechanisms to support an increase in renewable energy and energy efficiency. At the regional level, policy-makers have jointly established net billing as the appropriate minimum standard for policy support across CARICOM. Despite these important initial steps, sustainable energy development across the region continues to be limited by policy and data gaps, administrative ineffectiveness, and often inefficient and unco-ordinated implementation efforts (Worldwatch 2012).

As documented in the C-SERMS report, one of the biggest challenges to Caribbean governments is the often significant lack of capacity dedicated exclusively to sustainable energy issues. Energy units are ill equipped to tackle the substantial problem of converting traditional island energy systems to sustainable energy systems. Human capacity, small budgets, limited staff and diverse responsibilities all hinder progress. Energy units focused on renewable energy are often further burdened by a severe lack of consistent leadership and insufficient political will by the changing political directorate. Often, overlapping/opposing mandates and varying priorities among different government agencies and institutions lead to duplication, inefficiencies and unclear strategies. This challenge could be extended regionally. There are significant advantages to a regional approach, both in the sharing of knowledge and experience, and in terms of combined purchasing power. This is one of the reasons why the CARICOM energy policy and C-SERMS initiative are critical to future development of the sector (Worldwatch 2012).

The collection of energy sector statistics is often lacking within government organisations, leading to an inability to monitor progress or appreciate the level of energy sector issues – 'you can't manage what you don't measure'.[2]

5.4.7 Challenges to the investors

Investors interested in the Caribbean face a number of challenges. First, even though resources are substantial and expected LCOEs on different renewables are attractive, investor risk can be high given the lack of firm policy direction, regulation and legislation. With expected system lifetimes for most renewable energy technologies extending over 20 years, investors will be inclined to invest only in a stable market. Currently, guaranteed return on investment is not strong – this requires firm policy initiatives and stable price structuring.

There is often some uncertainty as to the extent of renewable resources of Caribbean countries, as in the case of the wind energy sector, where planning guidelines are limited by overburdened, under trained planning departments; knowledge of interconnection issues is low; electricity acts do not speak to the needs of independent power producers (IPPs); and wind resource maps are non-existent or at low resolution. A specific database/brochure for potential investors detailing technology options, costs and performance characteristics of typical renewable energy systems would be of help to potential investors.

Renewable energy proponents are often up against fossil fuel incumbents who, over many years, have accumulated knowledge of the inner workings of a country's,

and the region's, energy sector. Renewable energy investors are often left frustrated by their severe lack of lobbying power. Industry associations are beginning to emerge, such as BREA, which provides a much-needed industry voice to the many development issues of the energy sector and, along with the local UWI campus, helps to raise awareness among different government institutions, industrial bodies and the general public.

5.4.8 Challenges to the regional renewable energy sector as a whole

One of the key challenges to the region is the low consideration given to energy management and energy efficiency; yet this is simplest way to reduce national energy import bills. This challenge stems from the general low level of energy awareness among Caribbean populations. Many companies and institutions are under informed as to the potential for energy reduction and potential cost savings from first pursuing energy management and energy efficiency options, and of the impact that distributed renewable energy can ultimately have on their lives.

Local investment is imperative if the Caribbean is to install utility-scale wind energy – one of the cheapest, if not the cheapest, forms of any new generation technology worldwide. The transition towards a clean, sustainable energy sector offers a chance for nations to reclaim their energy systems through citizen/co-operative ownership of large-scale renewable energy plants. This model has been shown to create a more harmonious relationship between renewable energy operators and their surrounding neighbours. The experience in northern Germany is a prime example of this, where farmers are provided with an additional revenue stream, allowing them to maintain and improve the countryside. A local stake in such projects often translates to fewer planning issues for wind projects.

5.5 Key recommendations

The following recommendations emerged from interviews and survey responses from Caribbean energy stakeholders. They outline the key recommendations for different areas of the Caribbean energy sector. In addition, Hohmeyer (2014) provides insights into the immediate recommendations for a transition towards a clean Barbados energy sector, which are applicable to the wider region.

5.5.1 Governance

- **Multilevel ownership:** Greater local intra- and extra-governmental, and regional, co-ordination and co-operation. At the national level, there is scope for a mechanism for co-ordination of efforts in the renewable energy/sustainable energy arena; otherwise the approach will continue to appear disjointed and duplicative. Such a mechanism, particularly at the local level, will also minimise wastage in terms of capital and human resources. At the regional level, there needs to be a mechanism in place to facilitate the sharing of experience and best practice. There is also room for standards development at the regional level, a process currently being led by CROSQ (2015).

- **Commitment to a vision:** Energy visions need to be condensed into singular national plans that all stakeholders align with and take ownership of – *develop a plan, and then seek funding.*
- **Institutional strengthening:** In many instances, dedicated autonomous energy units are not the norm. Dedicated energy units tasked with informing and implementing energy policy are necessary. These units must be adequately staffed and empowered with supporting legislation and regulations.
- **Policy and legislation:** Many of the countries studied (with the exception of Barbados) have approved energy policies, but no proclaimed revised legislation. Antiquated legislation, which often speaks to one generation, transmission and distribution utility and has no provisions for IPPs and renewable energy advancement, is therefore still in effect in many territories. In many cases, revised policies and legislation are in the works, but have been 'in train' for some time. Such conditions do not augur well for investor confidence and increase risks, thereby increasing the cost of capital. Sustainable energy policies and legislation need to be articulated and enacted.
- **Strengthen or establish independent regulatory frameworks**: In some jurisdictions, such as Grenada, no independent regulatory body exists, while in others regulatory authorities need strengthening (Guyana). Where there is no regulator, the utility is often found to be self-regulating or controlled to some extent by government policy.

5.5.2 Development approach

- **Community involvement:** There is a need to involve as many citizens as possible in the planning and development of renewable energy, in order to spread the idea as widely as possible (i.e. explore the use of a community-investment model).
- **Involvement of all stakeholders from the early stages:** The experience of Dominica in its exploration of geothermal shows that it is crucial to involve all interested parties in the various development stages of large-scale renewable energy installations. Businesses and local residents will be naturally wary of new, unfamiliar technologies and, if they are kept under informed, then unsubstantiated and often false opinions may form (Dominican News Online 2015).
- **Ensuring a holistic developmental approach:** Resist fragmented funding of individual projects and seek to create an approach to RE development that first establishes the foundation elements to support a viable and sustainable RE sector. Investment at this stage, particularly from international donor agencies, should be focused on creating an enabling environment. There is a need to manage the enthusiasm of donor agencies to ensure that the mid- to long-term needs of recipient countries are adequately met.
- **Capacity building:** Capacity building is an area that requires particular attention. The local workforce must be empowered with the skill sets to take a project from conception to implementation. Technical, project management, project review and assessment, and negotiation skill sets are all required.

- **Ensuring exemplary project completion:** Mechanisms for improving execution and implementation of projects. Mechanisms for achievement of targets. There is a need to demonstrate the positive impacts of RE to gain greater buy-in.
- **Knowledge sharing:** Creation of a regional energy network that facilitates the sharing of knowledge, and of specific information about experience, successes and challenges. This can be used to inform policy and support successful implementation. Offer experience insight.

5.5.3 Technical considerations

- **Emphasis on a quality energy system:** Ensure that only high-quality products are installed in order to have a well-functioning and reliable power supply system.
- **Advocacy of 'demand side management'**: Citizens needs to be empowered with the knowledge and practical tools to take control of their consumption. This requires programmes that target behavioural and equipment specification modifications. Interruptible service riders, time-of-use rates and energy efficiency education are some of the tools that may be considered. There is a real need to educate the population about the individual's role in sustainable development, renewable energy and energy efficiency.
- **Smart grids:** Used primarily to enable better generation control. These will also help optimise the amount of variable energy sourced from wind and solar – the most widely available renewable energy resources in the Caribbean – which can be safely and reliably accommodated on the grid.
- **Electric vehicles**: The transport sector is responsible for between one-third and one-half of fossil fuel use throughout the Caribbean. Support policies and regulations should also be focused on this often-forgotten sector. The transition of transport sectors toward the use of electric vehicles will become of increasing importance as renewable energy penetration levels rise across the Caribbean.
- **Appreciation of energy use:** The public should be encouraged to understand and appreciate the true cost of electricity, particularly in jurisdictions where it is subsidised – such as The Bahamas and Trinidad and Tobago. The development of such awareness is expected to affect consumption patterns.
- **The construction sector:** Energy efficiency planning requirements for new buildings and energy efficiency standards for imported appliances and equipment should be developed.
- **Independent advice:** Secure, experienced, independent scientific and technical advice is needed for the entire transition process, in order to be independent of information from the power and oil companies, which might have vested interests not always coinciding with the long-term interest of the region.
- **Resource assessment:** Resource assessment data is needed for the various territories, e.g. between one and two years of wind resource data. This would encourage the conceptualisation of wind projects, as onshore wind has already reached grid parity.

- **Grid reinforcing:** There should be greater promotion of the use of automatic generation control at the grid level and less at the project level. This would be more financially prudent, as such costs would be incurred fewer times and would be spread across a wider customer base.

- **RE penetration studies**: Each grid is different; therefore, an approach based on best practice in dissimilar jurisdictions will not be appropriate. There is a need to ascertain the specific nuances of each island's grid and assess its ability to accommodate variable renewable energy with, and without, mitigation measures. Grid stability and reliability must not be compromised.

- **Stranded assets:** The facilitation of RE development through regulatory frameworks must be considered within the context of addressing the issue of potential stranded assets.

- **Importance of wind and solar:** Wind and solar, although variable in nature, represent the most significant potential for the collective and ubiquitous transformation of the electricity, and by extension the energy, sectors of the Caribbean. On average the region records insolation rates within the range of 5.2–6.1kWh/m^2/day (Hotspot energy 2011). With the falling cost of solar PV technology, this resource offers a tangible opportunity for average citizens to exercise some control over their individual/household electricity/energy security. This appears to be the trend in Barbados since the introduction of a Renewable Energy Rider programme, as the use of distributed solar PV, for both domestic and commercial activity, has realised an exponential increase over the past four years. It is understood that approximately 8MW of distributed solar PV has been installed, with a similar amount pending approval and installation. The national distributed variable RE capacity limit was revised from 9MW to 20MW in 2015.

- **Fuel adjustment clauses:** It is important to highlight that mechanisms linking the cost of energy generated from renewable sources to fuel surcharges, such as the aforementioned Barbados Renewable Energy Rider (see Barbados section), are impractical for the continued penetration of renewables onto the grid. Linking the cost of renewable energy to the international price of oil completely misses the point regarding the advantages of renewable energy, such as reduced price volatility and increased security of supply.

- **Storage:** Storage is not an immediate concern. Thanks to existing highly dispatchable energy systems, there is no need to build long-term storage facilities too early, as they will sit idle before the region reaches at least 50 per cent of renewable power penetration (however, there may be a need for some short-term storage to allow time-shifting of loads). This is supported by the BL&P's recent study on grid integration of wind and solar (Emera 2015).

- **Maintain existing infrastructure where possible:** Keep the existing power generation facilities as backup as long as possible, as they complement the expansion of renewable power supply very well.

5.5.4 Financial

- **Local investment:** Use a pricing policy for wind and solar power that enables broad local participation in the investment in order to generate additional income for as many citizens as possible. Set up the policy framework in such a way that the income generated from investment in new renewable power technologies remains within the local economy.
- **Targeted programmes for local banking institutions**: Retail banks offer instruments for the financing of green initiatives/projects in very few territories. There is therefore scope for education on the viability of renewable energy projects, and a need to put risks into perspective and seek to enable bankers to adequately assess renewable energy projects. Likewise, there is a need for capacity building, as it pertains to the efficient design of project proposals.
- **Insuring renewable energy systems**: Regional insurers are increasingly concerned about the quality of solar PV systems being installed, and an assessment is required of the various risks presented by the inclusion of PV systems on properties covered by existing insurance policies. Better-trained inspectors would help alleviate these concerns.
- **Power purchase agreements (PPAs):** PPA drafting is a crucial skill set for the utility-scale deployment of renewable energy. The Caribbean Electric Utility Services Corporation (CARILEC) has developed a PPA template for consideration by its member utilities. The PPA is the single document that determines the viability of an RE project and requires a multidisciplinary approach. Regulators need to be empowered with the necessary skill sets to assess such contracts.
- **Subsidisation**: Oil and gas subsidies should be removed in Trinidad and Tobago and The Bahamas. Retention of these subsidies hampers the development of renewable energy, as it appears artificially uncompetitive. Regulators also need to guard against cross-subsidisation, where the more economically vulnerable are required to maintain the grid, while RE customers benefit from use of the grid but do not contribute to its maintenance.
- **Low-cost capital:** Investors, particularly local investors, need access to low-cost capital. This is a significant inhibitor of local projects.
- **Creation of an appropriate investor climate:** Processes need to be streamlined to allow a receptive investor climate. Planning and permitting processes, economics, regulation and legislation and other bureaucratic processes should be reviewed.

5.6 Potential funding sources

Funding for renewable energy projects is increasingly available through local, regional and international banks and development agencies such as the CDB, the IDB, the

European Investment Bank, the French Development Agency and the Australian Development Agency. Some international development banks have prioritised the region as a lending environment in order to spur the development of renewable energy projects. Multilateral lending institutions, such as the International Finance Corporation, the IDB, the Central American Bank of Economic Integration and the Development Bank of Latin America, have all taken strategic actions to create linkages with private lending communities to facilitate funding for renewable energy projects. Local and foreign private investors are also beginning to become active in the process as the region's regulatory and legislative framework unfolds.

In April 2015, the United States committed to launching a US$20 million facility (the Clean Energy Finance Facility for the Caribbean and Central America) to encourage investment in clean energy projects. The facility is expected to provide early-stage funding to catalyse greater private and public sector investment in clean energy projects. It will draw on the expertise of the US Overseas Private Investment Corporation and the US Trade and Development Agency, in co-ordination with USAID and the Department of State.

Many of these institutions offer financing in a number of areas ranging from sustainability, environmental conservation and social/community empowerment to energy efficiency, energy security and resilience, technology development and innovation, institutional strengthening, electricity generation diversification, green tourism, clean transportation and energy education. It is difficult to ascribe a particular type of funding to a given agency, as it appears to be more dependent on the objectives of the agency at the time of application and the perceived feasibility of the project.

In addition, it has been noted by some of the funding bodies that there is often a lack of ownership of regional energy projects, which can lead to project failure due to poor maintenance regimes. Therefore long-lasting project success is dependent upon clear management rules, clear allocation of responsibilities and the inclusion of the persons who are affected by the project (in the community) to ensure that they feel a connection and are therefore willing to fully participate in ensuring its success. In a move to promote better ownership of projects, funders are exploring options such as the use of innovative financing mechanisms, such as blending loans and grants for development and project management by external contractors who are able to relieve often-overloaded local stakeholders (ECDPM 2013).

The secret to navigating these dynamic funding environments will be in the assembly of the right team armed with market knowledge, language skills and business acumen.

5.7 Vision 2050 for the Caribbean energy sector

Recent technological advancement in the renewable energy technology sector has mainly been in the area of manufacture, which has had a significant impact on economic viability. Today, some clean energy technologies have reached grid parity for large parts of the Caribbean, meaning that it is already significantly cheaper to

generate 1 kWh of electricity from some renewable energy technologies than it is to generate 1 kWh of electricity from existing fossil fuel generation plant (i.e. renewables can already play a 'fuel-saver' role). As most utilities work on timescales that account for the expected life of their generation plant (20 to 30 years), it is definitely conceivable that by 2050 the Caribbean's energy system can be 100 per cent based on clean, sustainable generation plant.

5.7.1 Resilient energy systems

- There will be increased levels of energy security, as a result of energy systems being decoupled from the international energy market. This will help the region to connect to the international community and develop on an economic and social level.
- Coupled to energy security will be the fact that, possibly for the first time in 400 years, the region can be 'master of its own destiny'.
- Overall the standard of living will increase and damage to the environment will decrease, while the ability to attract foreign investment should also increase because of the lower cost of doing business.
- There will be increased network reliability and resilience, as a result of a distributed network of RE generators.

5.7.2 Resilient economies

- There will be a reduction of government spending on energy and energy subsidies, allowing that money to be channelled instead towards critical areas in the national economies such as health and education.
- Money can stay within countries and be recycled, rather than leaking out in foreign exchange.
- The creation of different renewable energy technology sectors will allow development and diversification in new skill areas, leading to the availability of more green jobs.
- There will be room for innovation and income generation if the Caribbean is the leader in renewable energy development (at the moment this is not the case).
- A transition to clean energy systems will allow the development of a green brand of regional tourism – currently around one-quarter of income from the tourist sector is spent on energy.
- The cheaper and more stable cost of electricity can help attract manufacturing and clean technology industries.
- With the decline of the sugar cane industry and the importation of basic food items from international markets, the agriculture sector is suffering across many parts of the Caribbean. Renewable energy technologies can provide substantial economic relief to farmers, who can boost their incomes with the careful installation of solar, wind and biomass technologies.

- Clean energy technologies can also help with more advanced agriculture methods. The use of climate-controlled greenhouses and cool- and cold-water agriculture can improve food security in the region.

5.7.3 Healthier countries

- Not only will countries have more revenue for expenditure on health and education, but the generation of cheap, clean electricity from renewable technologies will allow a transition towards the use of electric vehicles on the region's roads. This would significantly mitigate noise and air pollution from vehicular transport.

5.7.4 Wider benefits

- A regional approach to solving the Caribbean's energy crisis will provide vital experience and facilitate the ability to adopt best practices from within the region, leading to better regional understanding and cohesion.
- A Caribbean actively pursuing a sustainable energy system will provide the region with the moral high ground in future climate change negotiations, and will send a strong message to the rest of the world that tackling climate change and transitioning from an almost 100 per cent fossil fuel-based energy system to a clean, sustainable energy system is indeed possible.

Notes

1 Telephone interviews conducted March/April 2015.
2 Quote from survey response, April 2015.

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