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2023

Market Overview

CARIBBEAN MICROGRIDS

Government of Canada | Gouvernement du Canada

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Table of Contents

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Two important sources of Caribbean energy data are the CARICOM Energy Knowledge Hub (CEKH) and the Energy Transitions Initiative managed by the National Renewable Energy Laboratory (NREL) of the U.S. Department of Energy. Both initiatives are supported by the Caribbean Centre for Renewable Energy and Energy Efficiency (CCREEE).

Watch Video

Canada Caribbean Microgrid Trade Accelerator Program

Geographical Scope

The Caribbean is a subregion of the Americas that includes the Caribbean Sea and its islands. Most sovereign states in the Caribbean (and one British overseas territory) are members of the Caribbean Community and Common Market (CARICOM), an international organisation that was formed in 1973 to encourage common policy and economic goals. This report uses the CARICOM regional group of nations consisting of 20 nations (15 full-time members and five associate members). This report does reference islands and countries beyond the CARICOM member nations (e.g., Dominican Republic and Puerto Rico) when information is highly relevant. See table below for list of CARICOM group of nations. There are more than 11 languages in the CARICOM including English, Spanish, French Dutch, and various creole languages.

Caribbean Community and Common Market (CARICOM) Members & Associate Members	
Antigua and Barbuda	Saint Kitts and Nevis
Bahamas	Saint Lucia
Barbados	Saint Vincent and the Grenadines
Belize	Suriname
Dominica	Trinidad and Tobago
Grenada	Anguilla
Guyana	Bermuda
Haiti	British Virgin Islands
Jamaica	Cayman Islands
Montserrat	Turks and Caicos

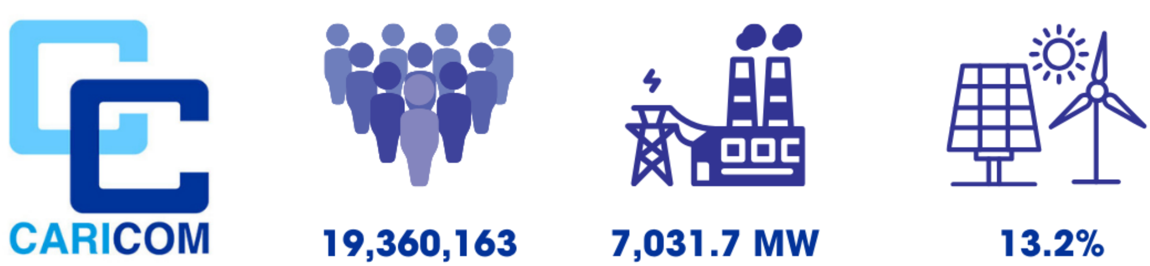
Snapshot - Energy in the Caribbean

VALUABLE REFERENCES

https://cekh.ccreee.org/cekh-resources/
https://www.energy.gov/eere/island-energy-snapshots

This section uses data from the CARICOM Energy Knowledge Hub (CEKH) prepared by the Caribbean Centre for Renewable Energy and Energy Efficiency (CCREEE) and the Island Energy Snapshots prepared by the National Renewable Energy Laboratory (NREL). Thes two sources include data for all 20 CARICOM nations (members and associate members) except Bermuda. Data for Bermuda was taken from sources that reference the Bermuda Light and Power Company.

The 20 CARICOM nations have a combined population of just over 19 million people being served by an installed capacity of 7,032. As of 2021, approximately 13% of generation capacity was from renewable sources. As shown in the second image, each nation varies in terms of population and energy supply mix. Please refer to Appendix 3 for data matrix.



Antigua & Barbuda
Population: 98,728
Capacity: 88.2 MW
RE share: 14.8%
Generation: 371.2GWh

Bahamas
Population: 393,500
Capacity: 1,300.2 MW
RE share: 0.5%
Generation: 1,663.7 GWh

Barbados
Population: 287,708
Capacity: 319 MW
RE share: 21%
Generation: 923.7 GWh

Belize
Population: 430,191
Capacity: 192.8 MW
RE share: 43.3%
Generation: 668.4 GWh

Dominica
Population: 72,376
Capacity: 27.2 MW
RE share: 26%
Generation: 100.8 GWh

Grenada
Population: 113,135
Capacity: 55.7 MW
RE share: 4.6%
Generation: 228.9 GWh

Guyana
Population: 790,329
Capacity: 348.6 MW
RE share: 16%
Generation: 902 GWh

Haiti
Population: 11,905,897
Capacity: 361.6 MW
RE share: 19.3%
Generation: 2,199 GWh

Jamaica
Population: 2,736,800
Capacity: 1,049.9 MW
RE share: 17.6%
Generation: 4,304 GWh

Montserrat
Population: 4,429
Capacity: 8.1 MW
RE share: 12.4%
Generation: 0.01 GWh

Saint Lucia
Population: 182,279
Capacity: 93.1 MW
RE share: 5%
Generation: 371.6 GWh

St. Kitts and Nevis
Population: 53,546
Capacity: 64.9 MW
RE share: 3.7%
Generation: 0.3 GWh

St Vincent and the Grenadines
Population: 110,295
Capacity: 52.5 MW
RE share: 17.9%
Generation: 153 GWh

Suriname
Population: 591,798
Capacity: 443.6 MW
RE share: 44.6%
Generation: 668.4 GWh

Trinidad and Tobago
Population: 1,367,559
Capacity: 2,118 MW
RE share: 0.5%
Generation: 8,804.5 GWh

Anguilla
Population: 17,422
Capacity: 26 MW
RE share: 8%
Generation: 0.1 GWh

Bermuda
Population: 64,000
Capacity: 172 MW
RE share: 0%
Generation: 650 GWh

British Virgin Islands
Population: 29,802
Capacity: 57.4 MW
RE share: 1.7%
Generation: 210.2 GWh

Cayman Islands
Population: 69,000
Capacity: 172 MW
RE share: 6.5%
Generation: 678.8 GWh

Turks and Caicos Islands
Population: 41,369
Capacity: 87 MW
RE share: 1.2%
Generation: 236.5 GWh

Challenges associated with energy in the Caribbean are linked to factors such as a heavy reliance on fuel imports, aging infrastructure, economic uncertainty, limited available capacity, and climate instability. The combined impacts drive up energy prices and have triggered the need for electricity subsidies in several island nations which can cripple an island economy starting with its utilities.

Post-COVID impacts have added stress to Caribbean economies due to their high dependency on external demand for resources, tourism, and finance. In 2023, supply chain disruption, resource demand, rising inflation and changes to access to financing continue to delay economic recovery. Additional challenges are presented by global economic shocks such as the Russo-Ukrainian War (e.g., contributing to fuel price volatility).

Even with CARICOM's continued efforts to develop the Caribbean Single Market and Economy (CSME), the CARICOM nations remain autonomous island states that present certain unique challenges when it comes to ensuring that energy is produced and electricity generated in a manner that ensures high quality, universal accessibility, as well as long term energy security at a reasonable cost.

Four key factors leading to energy insecurity in the Caribbean are:

1. reliance on expensive fossil fuel imports,
2. aging electricity infrastructure,
3. volatile economic activity,
4. natural disasters,
5. small scale markets,
6. limited access to finance, and
7. limited availability of capacity.

Recent investments into energy efficiency and renewable energy along with institutional, regulatory and policy reforms have improved the situation, but most islands now recognise the need for more and are committed to innovative economic diversification strategies with meaningful sustainability goals.

Energy Costs

According to 2022 World Bank reports, Caribbean consumers face some of the highest energy prices globally due to heavy reliance on expensive and volatile fossil fuel imports. Electricity prices in the Caribbean average around US$ 0.25 per kWh, more than double the average price in the United States and in some countries reaches over US$ 0.60 per kWh.

Montserrat (2021)	**Grenada (2015)**
Average Electricity Rates (USD/kWh)	Average Electricity Tariffs (USD/kWh)
Residential $0.39 – 0.57	Residential $0.425
Small Business $0.42 – 0.57	Commercial $0.442
Large Business $0.39- 0.54	Industrial $0.383
88% Imported Fossil Fuels	**98% Imported Fossil Fuels**

CCREEE ERC, 2021 *NREL, 2020*

Notable exceptions are Suriname which benefits from local hydroelectricity capacity and Trinidad & Tobago which has substantial energy subsidies, natural resources, and an active hydrocarbon economy.

Trinidad and Tobago (2015)	**Suriname (2020)**
Average Electricity Rates (USD/kWh)	Average Electricity Tariffs (USD/kWh)
Residential $0.04	Residential $0.04
Commercial $0.08	Commercial $0.07
Industrial $0.03	Industrial $0.07
99% Local Natural Gas	**60% Local Hydroelectricity**

NREL, 2020

Reliability of Electricity Supply

Most CARICOM islands have achieved 100% access to electricity for their populations and many see the electricity industry as a strong competitive advantage for the region. Exceptions are:

- Haiti (44% of total population had access to electricity in 2020)
- Guyana (89% of total population had access to electricity in 2020)
- Belize (92% of total population had access to electricity in 2020))
- Grenada (95% of total population had access to electricity in 2020)
- Jamaica (97% of total population had access to electricity in 2020)
- Suriname (97% of total population had access to electricity in 2020)
- Saint Lucia (99% of total population had access to electricity in 2020)

It is important to note that 'access to electricity' does not equate to 'reliable electricity'.

Some states and territories face challenges with power quality and reliability of electricity supply, mainly due to aging and damaged infrastructure. Power outages disrupt daily life, negatively impact businesses, and hinder present and future economic growth (e.g., disruptions in education).

Aging Infrastructure

Reported transmission and distribution losses are extremely low on some islands (e.g., Barbados 6%, Cayman Islands 5%, Turks and Caicos 6%) while other islands report extremely high losses (e.g., Haiti 50%, Guyana 32%, Jamaica 28%). Losses include technical losses of generated electricity during transmission and distribution, theft, and lack of payment. (CCREEE, 2021)

Fiscal deficits combined with electricity subsidies compound the problem on many islands (e.g., Dominican Republic, Jamaica, and Martinique) making access to capital for maintenance and repairs even more challenging.

While electricity subsidies can alleviate levels of fuel poverty (i.e., when more than 10% of a household's income is spent on energy bills), the cost of these subsidies strain the island's economy. Shortfalls in utility finances between revenues and costs are covered by subsidies from nation governments. In Haiti, "*EDH financial losses were recently estimated to be on the order of $200 million annually, equivalent to 4% of the national budget with subsidy levels on an upward trend over the past several years"* (Boston University, 2018).

Natural Disasters

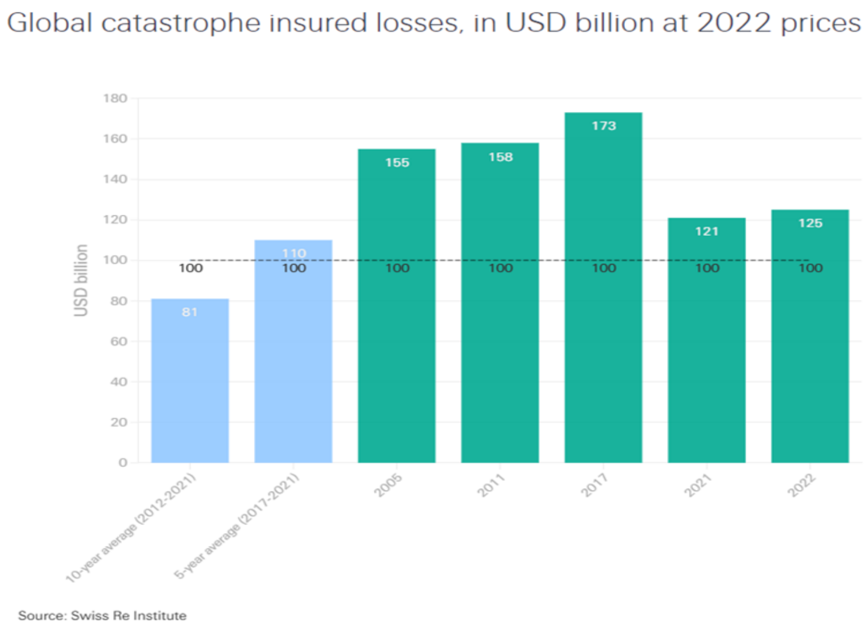
Disruptions to energy and road infrastructure in the Caribbean are mostly caused by natural disasters and climate instability. Hurricanes, floods and landslides are the most common culprits for disruptions to power supply.

The Caribbean's unique geography makes it vulnerable to storms. Five things that increase hurricane activity in the Caribbean:

- Warm water (i.e., above 26 degrees Celsius / 79 degrees Fahrenheit)
- Proximity to the equator
- Wind shear
- High relative humidity

On average, annual hurricane damage can cost the equivalent of 17% of an island's GDP. Damage to buildings, roads, power plants, electricity infrastructure, water and sanitation infrastructure are losses that take time and substantial capital to rebuild.

"*Global economic losses from natural disasters mounted to USD 275 billion in 2022. At USD 125 billion, insured losses covered 45% of the damage, the fourth highest total for a single year on sigma records.*" (Suisse RE, 2023).



Electricity service is usually one of the first crucial services to be disrupted with hazardous consequences from fallen poles and burnout of transformers. The consequences of damage from natural disasters in the Caribbean are amplified by challenges associated with evacuation as air and water travel as these are also disrupted by storms.

"Since 2000, hurricanes were the natural disasters with the highest estimated economic losses in the Caribbean."
Erick Burgueño Salas, 2023

According to the United Nations Economic Commission for Latin America and the Caribbean, Hurricane Maria in 2017 damaged or destroyed 95% of Dominica's housing stock and 226% of the nation's GDP and left 90% of Dominica's population without access to electricity for over four months (Commonwealth of Dominica, 2020). In Puerto Rico, Maria caused a systemwide collapse of the power grid that took 11 months to be entirely restored (Campbell, 2018).

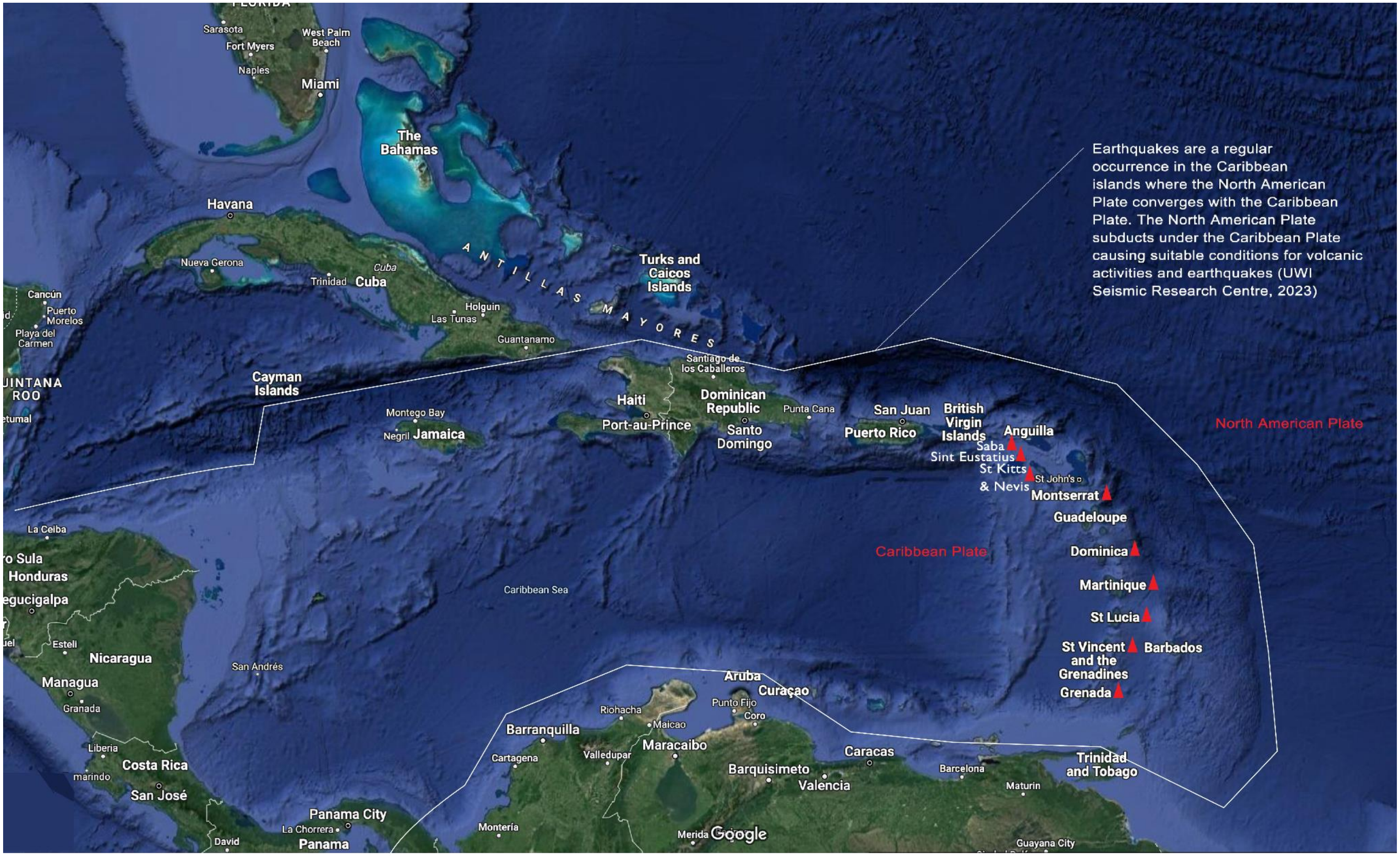
Hurricane Fiona in 2022 was a Category 4 hurricane that left the vast majority of Puerto Rico and its 3 million residents without power or water for several days and some for several weeks. Twelve provinces in the Dominican Republic experienced damage from landslides, fallen bridges, road blockages, power outages, interrupted telecommunications, and overflowing dams. These events highlight the vulnerabilities of the subregion's power sector and demonstrate the lasting, compounding, and increasingly frequent impacts of extreme climate disasters.

Lack of finance to provide strong hurricane resistant infrastructure and building codes that are either non-existent or not robustly enforced, means that the damage after hurricanes to housing stock, roads, bridges, and critical infrastructure such as hospitals and other emergency services can lead to significant numbers of injuries and death as well as homelessness or displacement after the storm.

The time taken after the storms to assess damage and then bring back communities and industries back online with service can lead to substantial economic losses. These can include loss of food due to the inability to keep foods and other stock refrigerated. This can affect both domestic users and owners of various industries that rely on refrigeration of food and other goods. Recovery time also has farther reaching impacts on working lives as schools shut down, leaving parents with having to find childcare, and long term consequences of affected school grades, most notably in the sciences.

The lack of electricity in of itself means that any industry relying on manufacturing will be unable to operate, and the general service industry will also be forced to cease operations until reliable power is returned.

Apart from tropical storms, one of the other natural disasters that can impact Caribbean countries and territories are earthquakes. The islands of the Caribbean generally lie on the ridge where the Caribbean Plate meets the Atlantic plant and that makes countries and territories in this region subject to earthquakes and volcanoes. These plates are moving in different directions which contributes to high seismic activity. The image below shows three earthquakes over a one-day period (August 23-24, 2023) in the region (https://earthquake.usgs.gov/earthquakes/map).


Earthquakes are a regular occurrence in the Caribbean islands where the North American Plate converges with the Caribbean Plate. The North American Plate subducts under the Caribbean Plate causing suitable conditions for volcanic activities and earthquakes (UWI Seismic Research Centre, 2023)
North American Plate
Caribbean Plate
Anguilla
Saba
Sint Eustatius
St Kitts & Nevis
Montserrat
Guadeloupe
Dominica
Martinique
St Lucia
St Vincent and the Grenadines
Barbados
Grenada
Trinidad and Tobago
Aruba
Curaçao
Puerto Rico
San Juan
British Virgin Islands
Dominican Republic
Haiti
Jamaica
Cuba
The Bahamas
Turks and Caicos Islands
Cayman Islands
Caribbean Sea
ANTILLAS MAYORES

> *"Most of the islands of the Lesser Antilles have a single live volcano that may erupt in the future (e.g., Nevis, Montserrat). The other islands are more complex, of which Dominica is the most extreme with no less than nine live volcanoes."*
>
> ***UWI Seismic Research Center***

Due to the infrequent cost of life or economic impact, maintaining preparedness strategies is challenging. Although volcanic activity and earthquakes rarely damage island communities, one incident can be devastating, as is the case in Montserrat where volcanic eruptions have resulted in complete destruction of the economy.

ACTUAL VOLCANIC DISASTERS IN THE EASTERN CARIBBEAN OVER THE PAST 300 YEARS

YEAR	VOLCANO	NATURE OF DISASTER (COSTS IN YEAR 2000 DOLLARS) *
1718	La Soufrière (St. Vincent)	Major explosive eruption. Unknown number of casualties amongst indigenous Caribs.
1812	La Soufrière (St. Vincent)	Major explosive eruption. About 80 deaths. Considerable damage to the sugar industry. Economic cost unknown.
1902	La Soufrière (St. Vincent)	Major explosive eruption. About 1,600 deaths. Considerable damage to the sugar industry. Economic cost estimated at US$200,000,000.
1902	Mt Pelé (Martinique)	Major explosive/effusive eruption. Over 30,000 deaths. Complete destruction of the city of St. Pierre. Other damage to agriculture considerable. Economic cost about US$1,000,000,000.
1976 – 77	Soufrière (Guadeloupe)	Minor phreatic (steam) eruption. No casualties but economic cost estimated at US$1,000,000,000
1979	La Soufrière (St. Vincent)	Moderate explosive eruption. No casualties but economic losses to the order of US$100,000,000
1995 – present	Soufrière Hills (Montserrat)	Moderate explosive/effusive eruption. About 20 deaths. Complete destruction of capital, Plymouth. Economic cost not yet estimated but in excess of US$500,000,000. Complete destruction of the economy.
2021	La Soufrière (St. Vincent)	Major explosive/effusive eruption. Damage to areas in the north of the island. No deaths. ~18,000 persons evacuated

Renewable Energy Developments

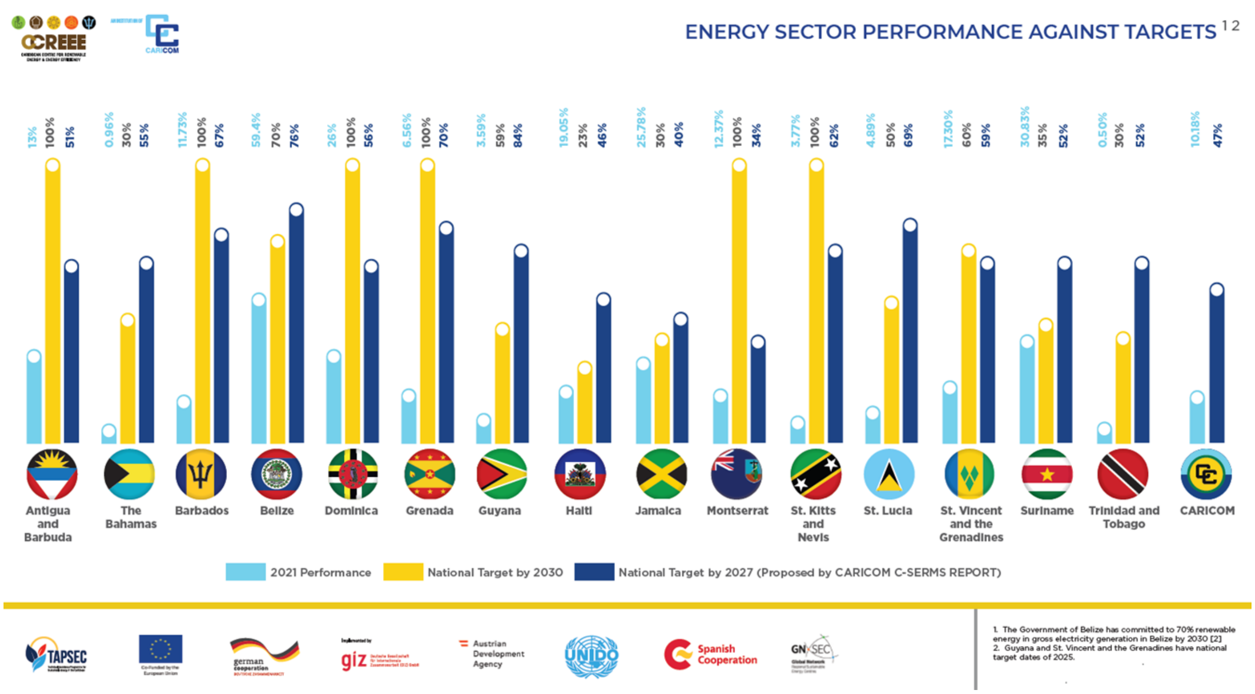
A move towards community-integrated decentralised energy and microgrids has prompted islands to take serious stock in local resources such as solar incidence, geothermal energy, wind profiles, ocean energy and green hydrogen. In 2016, CARICOM released a Sustainable Energy Roadmap that provided an overview of available renewable energy sources by country.

Country	Solar	Wind	Geothermal	Hydro	Biomass
Antigua and Barbuda	✓	✓			
Dominica	✓	✓	✓	✓	
Grenada	✓	✓	✓	✓	
St. Kitts and Nevis	✓	✓	✓		✓
St. Lucia	✓	✓	✓	✓	✓
St. Vincent and the Grens.	✓	✓	✓	✓	✓
The Bahamas	✓	✓			✓
Barbados	✓	✓			✓
Guyana				✓	
Haiti	✓	✓		✓	✓
Jamaica	✓	✓		✓	✓
Suriname				✓	✓

Source: CARICOM Caribbean Sustainable Energy Roadmap

Availability of resources is strong but much of the region is in its early stages of capacity development with four exceptions: Belize, Dominica, Jamaica, and Suriname. Hydroelectricity, geothermal and bioenergy are valuable for meeting base load demands. The La Bouillante power station in Guadeloupe already generates 15MW and development plans are advancing in Dominica, Nevis and Montserrat, and earlier stages of development in St. Vincent and the Grenadines. Solar and wind energy capacity is low in the CARICOM nations with installed wind energy capacity in Jamaica, Nevis, and BVI and utility-scale solar in Jamaica, Barbados, Bermuda, St. Lucia and Cayman Islands. Distribution-connected and off grid solar systems are becoming more popular in smaller community-scale projects, but current data is not readily available for the region.

In 2021, the CARICOM Energy Report Card reported that all 15 member nations had made progress towards their renewable energy targets.



Shared Challenges in Canada and the Caribbean

Canada and the Caribbean are different in so many ways. Canada is a country in North America consisting of ten provinces and three territories extending from the Atlantic Ocean to the Pacific Ocean and northward into the Arctic Ocean. Its total landmass area is 9,984,670 km^2 making it the world's second-largest country by total area. It is characterised by physical and climate extremes. Many of the country’s forests, rivers, lakes and wetlands remain in relatively pristine condition due to the low population density and its high-water availability. Climate instability is changing the Arctic region due to the high rate of warming and melting permafrost. The

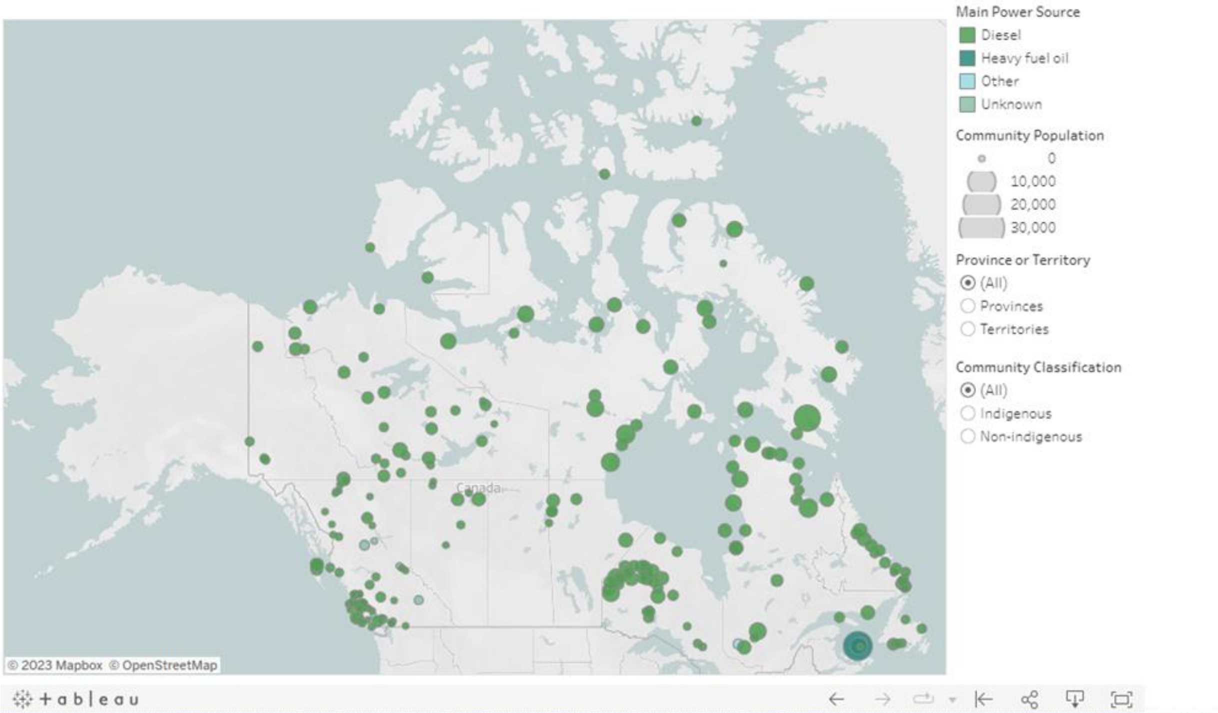
Great Lakes region holds over 20% of the Earth's surface fresh water – has been intensively managed over time in a collaborative way between Canada and the US.

A few of the similarities between Canada and the Caribbean in terms of energy are:

1. a desire to increase energy accessibility and reduce the cost of energy especially for underserved/ marginalised communities,
2. challenges associated with regional variations in resource availability and baseline carbon intensities,
3. disjointed codes, standards, and regulations across provincial/ territorial/ state boundaries,
4. increased need for resilient energy supply and fast recovery of critical loads due to natural disasters,
5. grid stability challenges associated with greater penetration of intermittent renewable energy resources, and
6. challenges associated with access to accurate and comparable energy data from different jurisdictions.

Rural and Remote Populations

Although not often recognised as such, one of the similarities between Canada and the Caribbean is the way that population centres are often located a significant distance away from each other. In Canada, nearly 18% of the population (i.e., 6.6 million) is rural. (Statistics Canada, 2021) The image below illustrates the number of remote communities that rely on diesel, heavy fuel oil or other remote electricity supply sources.



▼ Source and Description

Source: NRCan – Remote Communities Energy Database

Description: This interactive Tableau map shows the location of Canada's 283 off-grid communities (as of May 2017). The communities are colour coded based on primary power source. Of the 283 communities illustrated, 171 are Indigenous and the remaining 112 are non-Indigenous.

The vast size of the country and long distances with little or no population in between can be compared with 'islands' with large expanses of land separating them and as is the case with the Caribbean, Canada does not have a national grid but rather a multitude of disconnected regional grids.

Ways in which these land and sea 'islands' create similar challenges are in terms of the cost to connect the various centres together. Fuel transport in Canada often means significant costs of transporting fossil fuels resources over land (roads and railways) or water (ice roads or water vessels) add significant costs for a unit of energy in both town centres and smaller communities, including those serving indigenous communities.

The existence of underserved communities exists in the presence of indigenous First Nation communities in Canada brings with it a history of systemic marginalisation. Similarly, a history of colonisation and trans-

Atlantic slavery, has led to still lingering inequalities in populations along racial lines as well as class in many Caribbean territories. This has meant that many people in the Caribbean start with a level of poverty and lack of access to basic necessities which is difficult to overcome in one generation or even more.

Regional Economies

Another challenge that both the Caribbean and Canada face is the regional economies.

The Caribbean regional economies are supported by natural resources, fishing, agriculture, and tourism activities. The energy needed to support these activities relies on imported fossil fuels to provide 80% of the region's electricity supply. Only five CARICOM nations have oil and natural gas reserves: Barbados, Belize, Guyana, Suriname, and Trinidad and Tobago, and only Trinidad and Tobago and Guyana are net exporters of petroleum. The remaining electricity supply is provided by a mix of hydro, wind, solar, geothermal, bioenergy, and marine energy and potential varies by nation.

Canada's regional economies are supported by real estate, mining, and manufacturing activities. The energy needed to support these activities relies on hydropower to provide 59% of the country's electricity supply. 26% of the country's electricity supply is generated from uranium (15%) and natural gas (11%). (Canadian Energy Regulator, 2019) Other sources include coal, wind, biomass, petroleum, and solar and vary depending on the local resources of each province or territory.

Variations in primary sources of electricity combined with unique end use patterns (i.e., industrial, commercial, residential, transportation) brings challenges when regional collaboration efforts are targeted at sustainability strategies and emissions reduction plans. Strategies for achieving sustainable development goals are quite different when targeting petrochemical production versus electricity generation versus transportation.

Canada	CARICOM
Alberta	**Trinidad and Tobago**
Primary Electricity Source: ● 89% Fossil Fuels (Natural Gas, Coal, Coke)	Primary Electricity Source: ● 100% Fossil Fuels (Natural Gas and Petroleum
Electricity End Use: ● 75% Industrial ● 8% Commercial ● 5% Residential	Electricity End Use: ● 60% Industrial ● 10% Commercial ● 30% Residential
Sources of GHG Emissions: ● **52% Petrochemical Production** ● **11% Electricity Generation**	**Sources of GHG Emissions:** ● **60% Petrochemical Production** ● **30% Electricity Generation**
Quebec	**Suriname**
Primary Electricity Source: ● 100% Hydroelectricity	Primary Electricity Source: ● 60% Hydroelectricity
Electricity End Use: ● 40% Industrial ● 12% Commercial ● 20% Residential	Electricity End Use: ● 48% Industrial ● 19% Commercial ● 33% Residential
Sources of GHG Emissions: ● **38% Transportation** ● **26% Industries and Manufacturing**	**Sources of GHG Emissions:** ● **38% Transportation** ● **30% Electricity Generation**

Like any nation in the world, Caribbean nations have unique economies that are largely defined by their local resources thereby leading to varying proportions of industrial, commercial, and residential consumption demands. Each type of consumer comes with different usage patterns that have their own challenges.

Trinidad and Tobago, for example, is characterised by high levels of industrial energy demand. The relative abundance of oil and natural gas resources, as well as some other precious minerals, has developed an economy rooted in natural resources mining and intensive manufacturing including an aluminium plant that is one of the largest customers. Hence 56% of electricity consumption is industrial (i.e., large commercial). Guyana also has a similar profile with a large dependence on mining of minerals. Increasing offshore exploration has also led to recent discovery of oil and gas resources that have also led to expansion in that sector of the economy. Hence Guyana's electricity consumption is largely industrial (44%). Industrial energy demands are generally more predictable on a daily and seasonal basis than the daily peaks and seasonal variations of small commercial and residential electricity demands.

Jamaica's energy consumption is a predominantly residential and small commercial (58%) with a lower demand from large commercial (15%). One reason for the low demand for grid electricity from industrial customers is the substantial growth of Independent Power Producers (IPPs) in sugar processing (off-grid bagasse cogeneration) and bauxite/alumina industries (off-grid generation from gas/diesel/fuel oil). Although there are some arrangements to supply to the grid under certain demand conditions, most IPPs are not designed to export back to the grid. The remaining bulk of electricity demand is residential and small commercial which logically results in a demand portfolio characteristic of space cooling which have daily peaks and drops in demand.

"Air conditioners, refrigerators and other essential cooling solutions underpin the health, hospitality, education, wholesale and retail, commercial and residential sectors in the Caribbean. In the region, as much as 40–60% of energy usage is for air-conditioning."

Jamaica's National Cooling Strategy, 2021

Countries such as Barbados which have a greater dependence on the service industries such as tourism, also have an electricity use profile with daily peaks and drops, some are routine and others are dependent on variable conditions such as weather and occupancy.

Disjointed Standards and Regulations

> *"A standard is a document, established by a consensus of subject matter experts and approved by a recognized body that provides guidance on the design, use or performance of materials, products, processes, services, systems or persons."*
> ***ISO Definition***

In terms of governance one other similarity is that in the Caribbean each island or in some cases group of islands/ part of an island, is a separate country or political jurisdiction with its own distinct system of legislation and regulation.

In Canada industry-accepted standards (including guides and beneficial management practices) can facilitate commerce, international trade, and buyer acceptance. Standardisation can enhance credibility for domestic and international customers.

Specific advantages include:

- increased transparency to supply chain stakeholders on product quality,
- standardise product attributes (i.e., building code),
- reduce product wastage or assist in re-targeting product to other uses,
- provide a base for commerce/international trade or assist dispute mechanisms,
- enhance buyer confidence or credibility of a seller, and in some instances may deflect additional regulation, complement them or help address non-tariff trade barriers, and

- contribution to sustainability for the sector(s).

Natural Disasters

Natural disasters are becoming a shared problem throughout most of the world. Most recently, on September 8, 2023 a 6.8-magnitude earthquake killed over 2,000 people in Morocco. According to the US Geological Survey this was the strongest in the North African country's history.

The geological and geophysical nature of the Caribbean islands increases the likelihood of storms, earthquakes, and volcanic activity. This combined with the remoteness and recovering island economies makes the region particularly vulnerable. Canada indeed shares some of these vulnerabilities.

Taken from the Government of Canada public safety portal:

Earthquakes
Earthquakes are perhaps the most dangerous of all natural hazards. They resulted in the loss of more than a million lives worldwide during the 20th century.

Floods
Floods are the most costly natural disasters in Canada in terms of property damage. They can occur in any region, in the countryside or in cities, at virtually any time of the year.

Hail
Hail forms in the core of a thunderstorm. Water vapour in warm, rapidly-rising air masses (convection currents) condenses into water at higher, cooler altitudes producing heavy rain showers.

Landslides and snow avalanches
Landslides and avalanches have resulted in more than 600 deaths in Canada since 1840 and have caused billions of dollars in damage.

Tornadoes
Tornadoes are unmistakable rotating columns of high-velocity wind that brings devastation to anything in their path.

Tsunamis and storm surges
Tsunamis and storm surges are caused by different events but both result in flooding and damage to coastal areas.

Volcanic eruptions
Volcanoes may seem to be non-existent in Canada. There has been only one documented volcanic eruption in Canada in more-recent historical times, but there are many dormant volcanoes in western Canada, particularly in northwestern British Columbia.

Winter Storms
Winter storms are a reality for all parts of Canada. These severe storms typically involve a sustained combination of heavy snowfall, cold temperatures and high winds.

In 2022, severe weather in Canada caused $3.1 billion in insured damage making it the 3rd worst year for insured damage in history (Insurance Bureau of Canada, 2023). According to the Aquanomics report published in

2022, floods, droughts and major storms could cost Canada's economy $139 billion over the next 30 years with $14 billion in losses related to energy and utilities including direct damage to power grids and production plants as well as reductions in power output at hydro dams and nuclear plants because of low water levels (GHD, 2022).

The world is preparing for more natural disasters, whether it is high wind events in the Caribbean, Gulf Coast, or the US Southeast; floods in the Midwest; or fires throughout Canada and the USA, these catastrophic events highlight how vulnerable our fragile world is even in usual years, when the world is not facing a global pandemic. Food, water, and energy are critical to our survival. If a storm shuts down a central power plant or knocks down a transmission line, then populations, services, and businesses go dark. The many miles of power lines that deliver power to customers are both highly vulnerable and expensive to rebuild. As the world saw in both New York after Super Storm Sandy and Puerto Rico after Hurricane Maria, diesel fuel shipments for backup generation can be limited and unreliable, particularly if both ports and roads are compromised. More importantly, disruptions to power supply lead to follow-on disruptions to hospitals and other health facilities, water infrastructure, telecommunications, community service organizations, shelters, businesses, first responders, schools, and other critical facilities.

Integration of Renewable Energy into Electricity Infrastructure

Like many jurisdictions in Canada, some Caribbean jurisdictions are closely examining approvals of intermittent renewable energy capacity like wind and solar (as opposed to baseload capacity like geothermal and hydroelectricity).

This gives rise to the possibility that no further approvals will be given for new intermittent renewable energy projects. On August 3, 2023 the Alberta government said the Alberta Utilities Commission would be instituting a six-month moratorium on approving all wind and solar power projects greater than one megawatt. In Barbados, there are ongoing discussions over the possibility of curtailment of renewable energy supply if there is not significant investment and clear regulatory rules developed to govern the installation of storage.

If renewable energy is brought onto the grid above a technically determined threshold, this can potentially affect power quality and grid reliability.

Access to Data

Canada and the Caribbean share a critical challenge in that both lack a commonly accepted, authoritative and trusted source of information about electricity generation and delivery and the economic and environmental implications of regional variations. Although energy data sources are improving there are important data gaps, redundancies, inconsistencies and/or not accessible. In the Caribbean CARICOM and CCREEE are committing resources to improve this situation and in Canada the federal government is engaging more with industry associations and regional authorities to improve quality of data and accessibility. Until comprehensive energy information is provided by robust, independent and trusted sources our dialogues related to energy futures and sustainable development goals face deep challenges.

Summary of Similarities

- Presence of remote ‘island’ communities
- Separate governance for islands or provincial regions
- Cost of energy higher due to the dispersity of populations (although subsidies at times in place)
- Similar economy of scale issues related to dispersed populations
- Similar vulnerabilities of remote communities to natural disasters and climate change impacts
- Similar presence of underserved communities that have aspects of systemic impacts on ability to prosper
- Fossil fuel resources generally coming from a specific geographical location (Caribbean- Trinidad and Tobago and Guyana, Canada- Alberta, Saskatchewan, and Newfoundland and Labrador)
- Strong availability of renewable energy resources

- Limits to the amount of renewable energy generation that can be added on the grid without affecting grid stability

The Driving Forces of Microgrids

Microgrids are a subset of Decentralised Energy (DE) which is defined as kinetic and/or potential energy (thermal, radiant, chemical, nuclear, and electrical) that is created/stored close to the point(s) of consumption. It encompasses onsite energy generation, energy storage, and energy efficiency measures. DE projects vary in size and there is no set maximum capacity because systems are designed to meet a specific local load(s).

Microgrids, mini-grids and nanogrids are localised clusters of DE systems. Microgrids can operate connected to the distribution grid but are often designed to disconnect (i.e., "island mode") when grid outages occur. Mini-grids and nanogrids are fully autonomous with no grid connection. Interoperability is critical for microgrids, mini-grids and nanogrids and they must be designed to be responsive, dynamic, and automated.

Examples of DE (not limited to)

- District Energy
- Cogeneration and Combined Heat and Power
- Solar Energy
- Earth Energy
- Bioenergy
- Modular Reactors
- Microgrids, Mini-Grids, and Nanogrids
- Energy Storage

“In 1976, RMI co-founder Amory Lovins wrote ‘Energy Strategy: The Road Not Taken?’, which outlined his proposal for a ‘soft energy pathway’ for global security. In an era defined by large centralized electricity generation—primarily powered by coal and nuclear energy in the United States—where power was transmitted hundreds of miles from where it was generated to the businesses and people that consume it, Lovins’ soft pathway doctrine was based on decentralization. In this pathway, the generation of indigenous, renewable-powered electricity derived at or near the site where the energy was actually used would be lower-cost and more secure.” (Burgess and Locke, 2020)

The seven main drivers of microgrid adoption:

1) Global Commitments to Emissions Reductions: 197 countries have adopted the Paris Agreement and, of those, 179 have solidified their climate proposals with formal approval.
2) Traditional Electrical Grid Challenges: Expensive, limited functionality, and time consuming. The cost of delivering electricity continues to rise. In Canada, more than 50% of a consumer’s bill can be delivery charges.
3) Rise of Prosumers: When a consumer also produces energy, they are called prosumers. Many microgrids are developed by prosumers.
4) Digitalisation of Utilities: Digital information could unlock $1.3 trillion of value for the electricity sector. Four high-value themes are: asset life cycle management, grid optimisation and aggregation, integrated customer services and beyond the electron.
5) Lower Cost Renewable Energy and Storage: Solar PV modules prices are down ~90% since 2009 and wind turbine prices are down ~55-60% since 2010. Battery prices have also significantly decreased by ~87% since 2010.
6) Energy Resilience and Natural Disasters: Global economic losses from natural disasters mounted to USD 275 billion in 2022 (Suisse RE). The first half of 2023 reported preliminarily estimates at $194 billion and is expected to be the 5th highest economic loss on record.
7) Electrification of Society: The global transition to net zero has begun and electricity for data centres, transportation and agriculture will be required. Transportation alone will have deep impacts with more than 90% of all passenger vehicles in the U.S., Canada, Europe expected to be electric and autonomous by 2040.

IMPORTANT DEFINITIONS

Microgeneration – is defined as the small-scale production of heat and/or electricity from a low carbon source. The definition of 'small-scale production' varies widely but all maintain that the generation is off-grid or distribution-connected (not transmission-connected).

Net billing – Net billing is a market-based compensation mechanism, as prosumer compensation is based on the actual market value of the kilowatt-hours (kWh) consumed or injected into the grid.

Net metering – Net metering is a simple concept in which the electricity meter measuring the power consumed in a dwelling operates in reverse when excess power is generated.

Prosumer - Someone who both produces and consumes energy. Prosumers can be off-grid (relying on onsite energy storage) or on-grid (connected to the distribution grid).

Microgrids are the backbone of prosumerism. Prosumers install their own energy generation capacity to meet some or all of their electricity needs. Grid-connected prosumers behaviour generate electricity for their own consumption and export energy electricity to the distribution grid when it is most beneficial. Examples of beneficial times to export to the grid include:

1. when the prosumer does not need any electricity, or
2. when prosumers are offered incentives to export to the grid (i.e., peak times).

Mechanisms for managing prosumer exports to the grid vary and are becoming more sophisticated as prosumer capacity increases. Net metering, net billing and microgeneration regulations are examples of popular mechanisms for managing prosumer exports to the grid. In

Barbados, for example, a solar-powered microgrid has enabled residents to sell excess energy back to the main power grid.

There is a valuable role for prosumer engagement in:

- communities,
- educational institutes,
- healthcare facilities,
- hospitality, and
- industry.

By having access to reliable electricity, especially in remote and off-grid areas, communities in the Caribbean can benefit from microgrid systems. In the event of power outages, microgrids can enhance local economic activity, improve community resilience, and improve quality of life. The Caribbean is investing in microgrids to strengthen their power reliability, accessibility, and affordability. The island of Bonaire, for example, has a microgrid that integrates wind, solar, diesel, and battery storage to provide reliable and clean power to its residents.

Educational institutes such as universities, colleges and schools are ideal locations for microgrids to enable uninterrupted power to classrooms, laboratories, and research facilities. Added value comes from hands-on research and learning about renewable energy integration and grid stability. To reduce their dependency on fossil fuels and to provide educational opportunities for students and researchers, some Caribbean educational institutions are adopting microgrids. The University of the West Indies, for instance, has a microgrid project that combines solar PV, battery storage, and smart grid technologies.

The healthcare industry including hospitals, long-term care facilities, clinics, assisted living facilities, senior living facilities, prisons, and group homes are also well suited to microgrid systems ensuring continuous power for life-saving equipment, medical refrigeration, and other essential services. Reliable and resilient energy supply through microgrids can help maintain quality healthcare during emergencies and natural disasters. Some healthcare facilities in the Caribbean are using microgrids to ensure uninterrupted power supply for critical medical equipment and services. Schneider Regional Medical centre in St. Thomas, for example, has a microgrid consisting of solar PV, battery storage, and diesel generators to provide power during hurricanes.

As a result of microgrids, hotels, resorts, and tourist facilities can ensure uninterrupted power supply by improving resilience and reliability. In addition to reducing carbon emissions and improving the overall guest experience, microgrids can also be aligned with sustainability goals. Microgrids are being used by some Caribbean hotels and resorts to reduce energy costs and to be more environmentally conscious. The Cayman Brac Beach Resort, for instance, uses a microgrid to reduce its reliance on expensive diesel fuel by integrating solar PV, battery storage, and diesel generators. In 2022, the Royal Caribbean Group announced that its new Galveston terminal in Texas will be a LEED Gold certified building and the first cruise terminal to generate 100% of its needed energy through on-site solar panels. The opportunity for replication in the Caribbean is substantial.

Industrial entities in the Caribbean can benefit from microgrids in improving energy reliability, minimising energy costs, and reducing reliance on the centralised grid by using microgrids. Several industrial sectors in the Caribbean are exploring microgrids to optimise their energy consumption and production, including manufacturing and agro-processing.

Commitments to Emissions Reduction

CARICOM has also issued an overall policy framework which has served as guidance for several policy documents throughout the region.

Transparent policy documents that are set out with clear targets, strategies, and roadmaps to achieve desired outcomes and methodologies to measure progress on their attainment, stand a much greater chance of being effective. A government and energy sector inclusive of stakeholders that is moving in sync and has a clear idea of where they want to go will always be in a significantly more investment-attractive position.

In determining whether a country has the requisite characteristics to, first, develop a coherent policy with buy-in from stakeholders and, second whether the existing policies as articulated will be effectively enforced, there are a number of additional factors, following, that may to be considered.

Investment Trends

"The Microgrids market in the U.S. was estimated at US$3.5 billion in 2022. China, the world`s second largest economy, is forecast to reach a projected market size of US$22.2 billion by 2030. Among the other noteworthy geographic markets are the USA, Japan and Canada, and Germany." (Global Industry Analysts 2023).

The Rocky Mountain Institute acknowledges that geopolitical divisions are hardening in the global oil economy. Coupled with the impacts of intensifying climate change, countries, states, cities, and communities are acknowledging that a more decentralized energy system architecture comprised of distributed energy resources (DERs)—such as such as on-site solar, battery energy storage, and microgrids—is safer and more resilient in a rapidly changing political and environmental context.

Nowhere is the business case clearer or the need to transition to a soft pathway more urgent than the Caribbean. As already discussed, the CARICOM nations have high electricity costs, increasing natural disasters, and excellent renewable energy resources. Both this vulnerability and cost are inherently linked to a centralised electricity system running on fossil fuels. As a result of this unique set of ingredients, the region now finds itself center stage for the soft energy pathway…whether it wanted it or not.

Energy Resilience and Natural Disasters

As the planet continues to warm, increased moisture in the air will translate into even more severe and frequent tropical storms and hurricanes. The trend is alarming. There have been 34 Category 5 (CAT 5) hurricanes recorded in the Atlantic over the last 150 years. Ten of those CAT 5 hurricanes have come in the last 15 years—with five of those occurring in the last three years. The devastation seen with Hurricane Dorian in The Bahamas in 2019, Hurricane Maria in Puerto Rico in 2017, and Hurricane Irma affecting Barbuda, Anguilla, and the British Virgin Islands in 2017, all CAT5+ storms, are likely to become commonplace.

These conditions are not limited to the Caribbean. While California represents a different geographical context, it shares the same electricity system architecture of centralized power generation with transmission networks spreading hundreds of miles. Due in part to windy, dry weather that has increased the risk of fire, California utilities have repeatedly shut down the grid to avoid any chance of the type of power line accident that sparked the deadly wildfire in the small town of Paradise in 2018. The result of such forced outages has been millions of homes and businesses losing power for long periods of time. Regardless, those efforts did not prevent the Kincade Fire in 2019 from spreading throughout Northern California.

The economic impacts of the 2018 fires alone have been estimated at $400 billion—nearly double the annual budget for the entire state. The costs of the mandatory blackouts that California utilities have been implementing to try to avoid additional wildfire damage are exorbitant as well. Consider, for example, the cost of outages on schools: The proactive power shut-off implemented in 2019 during the Kincade Fire caused approximately 500,000 students to miss school, at an estimated societal cost of $14 million dollars per day.

Cost declines for solar photovoltaics (PV) over the last few decades and more recently for battery storage have allowed DERs such as renewable energy-based microgrids to be cost-competitive with the electricity grid. Recent RMI research summarized in the two Solar Under Storm reports from 2018 and 2020 shows that minor and cost-effective steps can be taken to ensure that solar PV systems can survive in the face of hurricane-force winds—keeping the lights on during and immediately after the storm. DERs and grid segmentation are critical to creating more resilient power systems at a time when climate change is putting more stress on grids. Whether islanded or connected to the grid, microgrids are becoming an important and increasingly favoured option over large-scale, centralized electricity generation.

Barriers to Microgrid Adoption

Two main barriers delay microgrid adoption:

1) Regulations and Governance
2) Economics and Investment Climate

Regulations and Governance

A general limitation of Caribbean countries with respect to governance and management in critical sectors is a lack of human capacity. Caribbean countries have skilled and trained professionals in critical areas. However, populations are relatively small. Moreover, the relatively small pool of expertise may be exacerbated by 'brain drain' where some pursue perceived greater opportunity elsewhere. Ministries and Departments with responsibility for energy may be understaffed.

This can result in a lack of a central authority, perhaps where there is no Ministry or Department specifically dedicated to energy. Further, professionals with responsibility in the energy sector can often also carry responsibility for important, related sectors such as environment, housing, water resources, physical development, or finance that inevitably demand a split focus, and dilution of resources and capability required in a time of energy transition.

As a consequence, there may not be a clearly identified point person to contact when issues of renewable energy are to be discussed. Further, there may not be a specific department with responsibility to enforce energy policies, whether clearly articulated and enshrined in legislation with government approvals, or simply priorities of government that are mutually understood by stakeholders.

Nonetheless, as noted above, there are now many governments that are moving to have stronger and more clear Ministerial focal points in energy and relevant Departments with clearly articulated mandates. Those which have had these institutional arrangements in place for a longer time are understandably more likely to have clearly defined energy policies in place that are more effectively enforced. The more successful energy policy and enforcement reforms are, the greater the domestic, regional or international investors' risk concern is alleviated.

Governments in the region may mitigate shortfalls in policy development or enforcement by gaining additional resources and capacity through financial assistance by way of Bilateral Agreements or regional and international development organisations.

Prospective investors may review a state's success at securing donations/funding, grants, loans or any other assistance which may reduce the risk of investment in renewable energy within the country. In the Caribbean, agencies that are active and keen to provide financial resources for renewable energy development, energy efficiency or large infrastructure projects include, The World Bank, The European Union (EU), the InterAmerican Development Bank (IDB), Caribbean Development Bank (CDB), CARICOM Development Fund (CDF) and the Organisation of American States (OAS).

Indicators that can demonstrate the amount of financial support the country has been able to gain from these international and regional agencies often can illustrate how conducive the governance, economic and regulatory environment is to new arrangements for energy delivery such as microgrids. (Rahman et al. 2016, 424). In addition, the World Bank's "CPIA rating for policy and institutions for environmental regulations and policies and implementation" is another useful indicator, as is the impact vulnerability index (see Buys et al. 2007) - which implies that states most affected by climate change may be more willing to undertake clean energy projects.

Investment Climate

Related to the likelihood of attracting financial aid or private capital is the investment climate within a country. Certainly, considerations of resource needs, relative lack of capacity and infrastructure and a lower GDP can make certain countries more eligible for grant donor funds. Yet, broadly speaking, countries are more likely to attract development and investment capital if they have strong governance and regulatory systems in place along with political and economic stability. Investors of all stripes crave certainty.

The development of microgrids will require significant investments in new infrastructure and capacity within electrical utilities and in the wider energy sector. It follows that the more attractive a country (or region) is for investment, the more likely it will gain the resources to successfully integrate microgrids.

The rank of a state's investment climate may be measured by the following indicators:

- Governance: voice and accountability, political stability, absence of violence, government effectiveness, regulatory quality, rule of law, and control of corruption
- Business Ready or B-READY (formerly Doing Business), The World Bank Group https://www.worldbank.org/en/businessready
- The World Bank's Country Policy
- Institutional Assessment (CIPA) rating for property rights and rules of governance (1=low to 6= high)
- CIPA rating for business regulatory environment (1=low to 6=high). (Rahman et al. 2016, 423-4).

Another factor relating to the investment climate and ability to attract financial aid is the amount of economic incentives present. Policy frameworks that are designed to promote renewable energy and sustainability in energy generally will tend to have economic incentives to support the activities or direction given through policy, regulatory and legislative instruments.

Incentives provided by countries seeking to increase renewable energy use and sustainability include:

- reduced corporate income taxes,
- reductions in value added taxes,
- feed in tariffs and subsidies to operators of renewable energy projects to compensate for their costs, and
- special tax regimes designed specifically for renewable energy products. (Rahman et al. 2016, 432)

Countries with higher CO_2 emissions and CIPA ratings are more likely to undertake clean energy projects while lower income countries are more likely to undertake other non-CO_2 reducing projects but were also more likely to take on bi/multilateral projects (Rahman et al. 2016, 433; 435).

The foregoing suggests that in determining which countries are better suited for microgrid development, Caribbean states that have higher governance and environmental CIPA values should be selected first.

In summary, countries where there is a strong policy framework in place present favourable opportunities for developments of microgrids. This is because, if the development of a microgrid is promoted or implemented showing the alignment of the goals and benefits of the project with the targets or goals or objectives of government policy, there is more likely to be buy in both from the government, the wider energy and electricity sector as well as with the general public.

Ways in which the development of a microgrid can align with goals and objectives of government policies are as follows:

- Energy Security
- Greater Penetration of renewable energy
- Resilience and recovery after natural disaster
- Diversity in ownership of energy and electricity products
- Overall energy costs to consumers
- Universal accessibility to energy services
- Mitigation and Adaptation to climate changes effects

Benefits of Microgrids

IMPORTANT DEFINITIONS

Decentralised Energy - Energy produced in proximity to where it is utilised. This is the opposite of a centralised energy system in which energy is produced at a distant location and delivered through transmission and distribution infrastructure.

Microgrid - A group of interconnected loads and distributed energy resources with defined electrical boundaries that acts as a single controllable entity and can operate in both grid-connected and island mode.

Benefits achieved through the deployment of microgrids include:

- Resiliency and accessibility as they are structured by many small production units instead of a few large units.
- Affordability is achieved through prosumer tariff structures, efficiency gains that come from shorter distances between production and consumption, and deferred costs of new energy transmission capacity.
- Increased scalability and modular growth compared to centralised energy systems.

The primary characteristic of a microgrid is its ability to function autonomously, even when disconnected from the larger electrical grid. It can operate in "island mode," meaning it can continue to provide electricity to the local community or facility during grid outages. Microgrids are often deployed in areas where the main grid is unreliable, in a remote location, or where critical facilities such as hospitals or military bases or key utilities are sited, that will need to be brought on with power almost immediately in the event of a disruption caused by a catastrophic event or natural disaster.

A microgrid can operate independently or in conjunction with the main power grid. It consists of distributed energy resources (DERs) such as solar panels, wind turbines, batteries, and backup generators which can be, along with control systems that manage the generation, storage, and distribution of electricity within a defined geographical area.

Resilience and Recovery

"Resilience is the ability to return to a predetermined path of development in the shortest possible time after suffering from an adverse shock."

UNDP Latin America and the Caribbean

By localising electricity generation and distribution, microgrids can provide enhanced resiliency. They can operate independently during grid outages and provide a reliable power supply to critical facilities and communities. Power grid resiliency can be improved using microgrids, which provide backup power when the grid goes down. For example, microgrids helped provide power to critical facilities such as hospitals and water treatment plants after Hurricane Maria hit Puerto Rico in 2017.

In addition to providing reliable energy during natural disasters or other emergencies, microgrids can also help reduce the risk of power outages during extreme weather events like hurricanes. Following Hurricane Irma, the Bahamas developed a solar-powered microgrid that supplies renewable energy to every home on Ragged Island.

Of course, the impact of the natural disaster is reduced if there is an electricity supply independent from the national grid available. This is not often the case in island states although with current work towards developing remote, distributed energy sources as well as microgrids. The impact of hurricanes and other extreme weather events can be somewhat mitigated.

It should be noted that another way in which microgrids can indirectly contribute to the mitigation of extreme weather events is through the use of renewable energy technologies, which is discussed in the section below.

The increasing frequency and intensity of hurricanes in the Caribbean can be directly related to climate change, which increases water temperatures and creates an environment conducive to the development of hurricanes.

The fact that microgrids in the Caribbean as well as elsewhere frequently are based on the use of renewable energy (mainly solar PV) means that the microgrid can contribute to reduce fossil fuel use and therefore have a concomitant effect on the reduction of carbon dioxide in the atmosphere. Reduction of carbon dioxide emissions reduces the climate change effect.

Accessibility and Reliability

Energy access can be improved with microgrids in remote and underserved areas where grid extension is economically challenging. It is possible to provide reliable and affordable electricity to communities that do not have reliable access to the grid. For example, minigrids and nanogrids which are not connected to the main power grid, are used to provide electricity to rural communities in Haiti.

Remote areas that lack traditional grid-sourced power connectivity can be provided with electricity using microgrids. By utilising renewable energy sources such as solar and wind power, they can also help reduce the cost of electricity generation. Several Caribbean countries have initiated a transition to local energy resources connected to the electricity grid at various locations.

Given that many remote locations in the Caribbean have high accessibility to renewable natural resources such as hydro and wind, microgrids allow for those energy sources to be used to power communities in that locality. ‘Island mode’ operation allows these resources to be stored within the microgrid, reducing the need for transmission and distribution that is required for energy obtained from the central grid.

Affordability

The integration of renewable energy sources, increased energy efficiency, and optimised system design can reduce energy costs for microgrids. Using renewable energy sources such as solar and wind power, microgrids can reduce the cost of electricity for consumers. This affordability factor makes microgrids attractive options for reducing the cost of electricity to consumers. Using a solar-powered microgrid in Jamaica, for example, has reduced the cost of electricity for residents.

Microgrids can provide consumers with cost savings by reducing their reliance on traditional grid-sourced power connectivity. They can also help reduce the cost of electricity generation by using renewable energy sources such as solar and wind power. By maximising net economic benefits from renewable energy, energy efficiency, and resilience, a sustainable energy pathway scenario could yield US$16 billion in net economic benefits over the next 20 years to CARICOM countries.

It is possible for Caribbean countries to defer major investments in traditional grid infrastructure by utilising microgrids. Microgrids provide an alternative power source to centralised grids, thus reducing the need to upgrade infrastructure. They complement the centralised grid and alleviate strain. By providing an alternative power source, microgrids can help defer the construction of new infrastructure. For example, in the Bahamas, instead of building a new power plant, a microgrid was installed at a resort to provide backup power during outages.

The potential for microgrids in the Caribbean can be significantly impacted by deferred infrastructure investments. According to a study by the Inter-American Development Bank (IDB), Latin America and the Caribbean should invest US$2,220,736 million in the water and sanitation, energy, transportation, and telecommunications sectors to expand and maintain the infrastructure necessary to meet the Sustainable Development Goals.

A 2006 Economic Analysis conducted by Decentralised Energy Canada covered a twenty-year period from 2005 to 2025. Over this period, electricity demand in the City of Calgary was modelled to increase at an annual rate of 2.3%. The study determined that distribution-connected generation has the potential to reduce capital costs by $1.1 billion in terms of present-day dollars, or 22%, between 2005 and 2025, and to decrease 2025 incremental power costs by $0.033/kWh or 28% as compared to transmission-connected generation. The avoidance of transmission and distribution losses improves the energy efficiency of the system as a whole.

Increased Grid Stability through Storage

One of the main challenges to utilities in the Caribbean as the penetration of the use of renewable energy increases, is that of grid stability. As renewable energy particular solar PV systems increase their presence on the grid, there is concern in many places that there will not be technical capacity to add more systems without affecting overall stability of the grid. Investment in storage capacity is seen as one of the ways to combat this, but this has been much slower in terms of development and implementation than is needed.

For microgrids, storage through batteries is often an element in the design which aids flexibility and potentially adds grid stability. it also potentially allows for greater use of EVs both as a load and a source of storage, therefore reducing any increased strain on the central grid that could occur as a result in the increase of these vehicles in the market.

Case Studies - Microgrids in the Caribbean

Rural Solar Microgrid Project, La Sabana Real, Dominican Republic

Status: In Construction

Capacity of Microgrid: 55.2 kW

The remote and isolated village of La Sabana Real (municipality of La Descubierta, province of La Independencia) near the national border to

Haiti, did not have electricity among other services (Presidencia de la Republica Dominicana, 2021). The village, whose main industry is coffee production, has experienced population flight as worries for extreme weather and economic challenges have taken hold (Cohn 2022). Having access to electricity would enable economic and educational advancement as school children would have access to internet and light after dark (Cohn 2022).

The German Agency for International Cooperation (Deutsche Gesellschaft fur Internationale Zusammenarbeit GIZ GmbH) presented the utility, Empresa Distribuidora de Electricidad del Sur (Edesur Dominicana) with the pilot project. The project is an initiative of the Ministry of Mines and Energy will benefit more than 75 families in the region supplied by Edesur. Management of funds (35 M Dominican Pesos) for the project will be under the supervision of the Ministry of Economy, Planning and Development (Guzman 2023; Presidencia de la Republica Dominicana 2021).

The project consists of a solar photovoltaic microgrid which will allow 115 households to receive solar generated electricity for the first time (Presidencia de la Republica Dominicana 2021). It includes 120 solar PV of 460W for a total generation capacity of 55.2 kW, and an independent 215.04 kWh energy storage bank of 42 batteries (of 5.12 kWh each) guaranteeing 48 hrs of continuous electricity (Presidencia de la Republica Dominicana 2021; Proyecto Transición Energética 2022). The government hopes that projects like these will offset the costs of continuously rising fuel prices (Presidencia de la Republica Dominicana 2021). Construction of the micro grid pilot was underway in mid-July (EH+ 2023).

Ragged Island Microgrid, The Bahamas

Status: Completed December 2021

Capacity of Microgrid: 390 kW Solar PV; 3,000 kWh Battery Storage

The Bahamas spans over 700 islands, thirty of which are populated (Stone, 2022). The Bahamas is 92% dependent on fossil fuel imports, thus the Government of the Bahamas decided to greatly reduce its dependence on volatile fossil fuel prices and power outages caused by extreme weather increasingly caused by climate change and an antiquated electrical grid system (Wood 2019). In addition, it costs $0.30 USD/ gallon to ship the fuel that is already $6/gallon (Sheehan and Quinn, 2023). Schools must be let out because not only do instruments not work, fans and air conditioners don't function making it too hot to participate (Stone, 2022). The Government collaborated with the Rocky Mountain Institute, and Bahamas Power and Light (BPL) (the publicly owned utility which services 21 of the islands) to initiate several projects (predominantly solar PV microgrids) in 2015 and implement a least-cost energy system alternative to fossil fuels (Wood 2019). Locations of the projects include Highbourne Cay Island, Chub Cay Island, Over Yonder Cay Island, Ragged Island, New Providence (Nassau) Island, and Abacos Island (Stone 2022).

BPL subsidises the price of electricity on the Family Islands (a group of inhabited islands also known as the Out Islands), therefore losing money, and not making any profit (Stone, 2022). The microgrids help BPL offset the losses however the savings aren't being transferred to the customers yet, more RE generation is needed (Stone, 2022).

Ragged Island has a population of approximately 65 people, who had their energy infrastructure largely destroyed by Hurricane Irma, making many homeless and without a source of income for months (Wood 2019; Ward 2022). Five years after Irma, Ragged Island became the first Bahamian Island to be powered by 390 kW solar PV microgrid with a 3,000 kWh long lasting battery (Ward 2022; Wood 2019). The project cost $5 M USD and was completed by Bahamas Power and Light (BPL) with initial planning from the Government of the Bahamas and the Rocky Mountain Institute (Ward 2022). It was the Government's intent that Ragged Island would be the first island to be fully energy sustainable and resilient to extreme weather (Ward 2022). The project was put on hold as other hurricanes subsequently hit other parts (Abaco and Grand Bahama) of the Bahamas, and emergency attention was required for those areas. Additional delays were caused by the location of the two main subcontractors who were based in Freeport (a city in Grand Bahama affected by the hurricanes) and the supply chain disruption brought on by COVID-19 (Ward 2022). The solar PV system was built on high ground with underground wiring and according to RMI's Solar Under Storm Best Practices (Wood 2019). The microgrid came online in December 2021 (Wood 2019; Ward 2022).

Chub Cay Island Microgrid, The Bahamas

Status: Completed

Capacity of Microgrid: 4 MW Solar PV; 5 MWh Battery Storage

The Chub Cay Island microgrid is a solar PV and battery storage system powering the Chub Cay Resort and Marina (Cohn 2021). The resort is in a hurricane prone area with high salinity conditions given its location of 1,000 ft from the ocean (Crowell 2021). The resort relied on two Tier 2 diesel generators, which needed to be shut down by Compass Power during extreme weather events to protect the equipment (Cohn 2021). With the new microgrid, the diesel generators will operate 10% of the time instead of 100% of the time thus reducing fossil fuel use by 90%, reducing energy costs by 50% by switching to RE (Crowell 2021).

The 4 MW microgrid consists of 2 -5MWh lithium-ion batteries and 4 bi-directional 1,000 KVA PCS inverters, and will generate 6,785 MWh of energy annually (Crowell 2021). It is the largest (in 2021) autonomous and independently operated microgrid in the Bahamas (Cohn 2021; Crowell 2021). The project, funded by the Resort and executed by Bahamian EPC Compass Power, took 8 months to complete and employed primarily Bahamian labour (Cohn 2021; Crowell 2021).

The size and remote location of the projects were the main challenges to logistics. A complex and detailed engineering program was needed, and better understanding of the full BOM, equipment and tooling was required to execute the work said Justin Cunningham, general manager of Compass Power (Crowell 2021). Geotechnical surveys were done to find the soil composition and capacities - ground screws (2000 of them, each 4" in diameter and 82" long) were found to be the only structural and financially viable solution to penetrate the island’s solid oolite limestone than driven piles in concrete foundations (Crowell 2021; Cohn 2021). The companies involved (Compass Power, Terrasmart et al.) customized the microgrid system to withstand hurricane-force winds up to 185 mph (such as Hurricane Dorian) and gusts up to 210 mph with a low-tilt and a specialised module frame to ensure durability. There were six mounting locations instead of four to secure the modules to the racking structures to achieve the required uplift ratings. The battery system structure was also built to withstand the same environmental conditions. The array also has a lightning protection system.

Compass Power started in 2005 and based its business on traditional power systems dependent on fossil fuels, however, following legislative changes, the company decided to move into RE (Cohn 2021).

Thomas A Robinson National Stadium Solar PV Car Port Power Plant, New Providence, The Bahamas

Status: Completed 2019

Capacity of Microgrid: 925 kW Solar PV

The Solar Car Park is a 925- kW Category 5 Hurricane resistant solar microgrid and was made possible with grant support from the Government of the United Arab Emirates (Wood, 2019; Adderley, 2019). It was developed under the $50 M USD UAE-Caribbean Renewable Energy Fund (CREF) in partnership with the Bahamas Ministry of Environment and Housing, and with initial concept support from the Rocky Mountain Institute (Adderley, 2019). It opened March 18, 2019. The project includes a carport with 342 parking spaces, including two stations that are for fast-charging electric vehicles (Vedrine 2019). Energy generated from the solar panels will feed into the national grid and offset some of the electricity used by neighbouring schools (Vedrine 2019).

Paraquita Bay Solar, Battery Storage, and Substation Project, British Virgin Islands

Status: In Development

Capacity of Microgrid: 2.5 MW Solar PV; 8.5 MW Battery Storage

Hurricane Irma hit the British Virgin Islands in September 2017, as a Category 5 storm its winds went up to 185 miles per hour causing severe coastal and inland flooding and destruction to infrastructure: over 80% of houses were destroyed (Government of the Virgin Islands 2019). Hurricane Maria, another Category 5 storm, hit thirteen days after Irma, killing a total of 4 people and injuring 125. The hurricanes destroyed approximately 90% of the electrical grid, and severely damaged the Territory's only power plant (Government of the Virgin Islands 2019). The government with support from the Rocky Mountain Institute thus developed a whole-systems approach in seeking to establish a lower cost and resilient electricity system (Government of the Virgin Islands 2019).

There was $600,000 worth of grant funds through the Caribbean Development Bank (CBD), provided by the Canadian Support to the Energy Sector in the Caribbean Fund to help with the technical assistance (Shefchik 2022). The funds are being managed by the British Virgin Islands Electricity Corporation (BVIEC), a government owned utility, and BVIEC's process of procuring contracts will be reviewed by the CBD (Shefchik 2022).

The Paraquita Bay Project is the second microgrid project initiative in the British Virgin Islands (BVI). The project will include a 2.5 MW utility-scale solar PV system, 8.5 MW battery storage, power management systems, a substation and will require transmission underground cables to integrate into the existing fossil fuel energized grid system in the BVI and can decouple from the grid to provide local electricity during a power outage (Shefchik 2022; Stone 2023; BVIEC 2022; Rocky Mountain Institute 2021). Challenges for the project included issues with land acquisition (Shefchik 2022).

Within the Paraquita Bay Community, is a community college which is a designated hurricane shelter, a water pumping station, and a water treatment plant which will receive power from the microgrid decoupled from the national grid in the event of extreme weather or an electrical fault (Stone 2023).

The project presented an opportunity to study energy storage (battery) optimization by analysing the activities which would add value and quantify the main and side financial benefits that the batteries could deliver in small island grids. For example, spinning reserve support can help conventional generators perform at their optimal operating point, reducing fuel consumption and lead to lower bills to customers (Stone 2023).

After submitting the project for tender, the BVIEC announced that it had given the qualifications to seven engineering, procurement, and construction firms to develop the new clean energy and microgrid system (BVIEC 2022).

Mayreau Microgrid Project, St. Vincent & the Grenadines

Status: Commissioned 2023

Capacity of Microgrid: 150-200 kW Solar PV; 100-250 kWh Battery Storage

The St. Vincent Electricity Services Limited (VINLEC) is the government owned utility which generates electricity through its diesel power or hydro plants, as well as 2% of annual production of RE through solar farms depending on which island it is servicing (St. Vincent Electricity Services Limited 2020). Working with the Rocky Mountain and Carbon War Room for technical advising and project management, VINLEC initiated the Mayreau project so that the island could become the first of the four Grenadine Islands served by the utility, to have its energy needs largely provided by RE (Rocky Mountain Institute 2023). Funds for the project were provided by VINLEC and the Ray and Tye Noorda Foundation. The Mayreau Microgrid Project will consist of 150-200 kW solar PV, and battery storage for 100-250 kWh (Rocky Mountain Institute 2023). The project managers released a Request for Qualifications for contractors to submit credentials to bid for the Engineering, Procurement and Construction contract in April 2023 (Rocky Mountain Institute 2023).

The small size of the island presents the challenge that everything one requires needs to be transported from St. Vincent or Union Island, thus the microgrid would offset operation costs, while increasing energy security and resiliency (Rocky Mountain Institute 2018). Energy costs would be lowered since the solar and battery storage will quiet the diesel generators 6-10 hours/day reducing not only GHGs but noxious noise from the generators (Rocky Mountain Institute 2018).

The Montserrat Solar PV Project, Montserrat, Lesser Antilles

Status: Completed in 2021

Capacity of Microgrid: 750 KW Solar PV; 1 MWh Battery Storage

The importation of fossil fuels accounts for half of the electricity cost in Montserrat, making it one of the highest electricity rates in the world (Stone 2021). The Government of Monserrat worked with the Rocky Mountain Institute and the Montserrat Utilities Limited to install the 750 kW ground mounted solar PV system of 2000 panels along with a 1 MWh of battery energy storage which is enough to power 300 homes, and was funded by the European Union EDF11 Program (Stone 2021; Golden Media 2021; Energy Unit 2021). The project was designed to allow for expansion in installing additional panels and battery storage systems in the future on land contributed by the Royal Montserrat Defense Force (Golden Media 2021). The Montserrat solar PV microgrid created local job opportunities and raised awareness on the importance of RE (Stone 2021). The system allows Montserrat to be 50% dependent on RE, by integrating into the existing grid, which could be disconnected when needed (Stone 2021). Technical specifications included making the microgrid system resilient to hurricanes (designing for 180 mph winds and Exposure Category C for hurricanes), corrosive sea blast, coastal land, and followed local codes and international best practices (Stone 2021).

The principal challenge were the financial constraints for the project given the size of Montserrat's economy. Grant funding was key and will remain as such for future projects (Stone 2021). Another challenge was in designing the project so that it would pose zero risk to flight operations in order to obtain approval by the aviation authorities. The glare from the solar panels could affect visibility for pilots flying and to air traffic controllers from the airport tower (Golden Media 2021).

Solar Park Project, Piarco International Airport, Trinidad & Tobago

Status: In Commission Phase

Capacity of Microgrid: 0.5 MW Solar PV

The ICAO conducted a feasibility study for RE at Piarco International Airport to reduce emissions from international flights. The ICAO-EU project supported the Government of the Republic of Trinidad & Tobago in developing an action plan to reduce emissions as per their commitment to the UNFCCC Paris Agreement. A feasibility study was conducted to identify and subsequently recommended six sites which could host the solar panels (Khan-Labban). The ICAO-EU report analysed the electricity usage at the airport over a period of ten years, conducted a financial analysis, and determined how much potential solar energy generation could be produced annually from the six different sites (Khan-Labban). Finally, the location nearest the existing car park was chosen to host the solar PV panels over 1.54 hectares (Delegation of the European Union to Trinidad and Tobago 2020; Ministry of Planning and Development 2023). The report identified two key challenges which were securing investment commitment, and government policy commitment which would support the implementation of the project (Khan-Labban).

Once the positive results were delivered by the ICAO-EU feasibility study, the Global Climate Change Alliance funded by the European Union awarded a grant of 1.5 M Euros to finance the installation of the large scale 0.5 MW solar PV system (GCCA+ 2020; The National Gas Company of Trinidad and Tobago Ltd. 2022). The ground mounted panels, which are expected to operate for twenty-five years, will generate 767,034 kWh and offset the equivalent emission of 500 metric tons of carbon dioxide annually (GCCA+ 2020; Trinidad and Tobago Guardian, 2023). The main intent of the project is to further reduce carbon emissions from aircrafts by switching approximately 7.2% of the consumed electricity by the Airport Authority of Trinidad and Tobago (AATT) from fossil fuels to a renewable and local source (GCCA+ 2020). The solar farm microgrid is being managed by the Trinidad and Tobago Airports Authority (Trinidad and Tobago Guardian, 2023).

In February and March, 25 tonnes of solar PV ground mounted structures, 960 PV modules, a transformer and high voltage cables were installed, along with fibre optic cables and a drainage system (Trinidad and Tobago Guardian, 2023). The Minister of Planning and Development stated the next steps were to complete the electrical wiring, drainage, and grounding systems; installation of inverters, SCADA (Supervisory Control and Data Acquisition for machines and processes in real time) and CCTV, as well as the pre-commissioning process which was expected at the end of March 2023 (Trinidad and Tobago Guardian, 2023).

APPENDICES

1. References

Adderley, Morgan. “$4m solar car park opens at stadium,” The Tribune, March 19, 2019, http://www.tribune242.com/news/2019/mar/19/4m-solar-car-park-opens-stadium/.

Biderman, Rachel. "Should a Devastated Caribbean Leap Forward to Renewable Power and Microgrids?" IEEE Spectrum, October 5, 2017. Accessed August 13, 2023. https://spectrum.ieee.org/should-a-devastated-caribbean-leap-forward-to-renewable-power-and-microgrids.

Burger, Andrew. “Seven Solar Plus Storage Microgrids Live in the Bahamas; More to Come,” Solar Magazine, https://solarmagazine.com/seven-solar-plus-storage-microgrids-the-bahamas-more-to-come/.

Burgess, Christopher and Justin Locke. “Beyond 60 Minutes: The Caribbean, Center Stage for the Soft Energy Pathway.” March, 202. https://rmi.org/beyond-60-minutes-the-caribbean-center-stage-for-the-soft-energy-pathway/

BVIEC. “Seven Firms Qualify to Progress Resilient, Clean Energy in Paraquita Bay,” British Virgin Islands Electricity Corporation Press Release August 9 2022. https://bvielectricity.com/seven-firms-qualify-to-progress-resilient-clean-energy-in-paraquita-bay/.

Caribbean Centre for Renewable Energy and Energy Efficiency (CCREEE). “2021 Energy Report Cards.” CARICOM Energy Knowledge Hub (CEKH). 2021.

Caribbean Development Bank, “Procurement Notice,” Caribbean Development Bank https://www.caribank.org/work-with-us/procurement/procurement-notices/microgrid-project-paraquita-bay-island-tortola.

Caribbean Development Bank. "Keynote Address: Energy Transition in the Caribbean - Challenges and Opportunities." *Caribbean Development Bank Newsroom*, https://www.caribank.org/newsroom/news-and-events/speeches/keynote-energy-transition-caribbean-challenges-and-opportunities.

Cohn, Lisa. "Building a Microgrid that Stands its Ground in the Storm-tossed Caribbean," Microgrid Knowledge, August 10 2021. https://www.microgridknowledge.com/editors-choice/article/11427800/building-a-microgrid-that-stands-its-ground-in-the-storm-tossed-caribbean.

Cohn, Lisa. "Caribbean Ripe for DER and Microgrid Development but Needs Financial Boost." Microgrid Knowledge, May 14, 2019. Accessed August 13, 2023. https://www.microgridknowledge.com/distributed-energy/article/11428826/caribbean-ripe-for-der-and-microgrid-development-but-needs-financial-boost.

Cohn, Lisa. "Dominican Republic villages seek to electrify with solar microgrids, reflecting global trend," Microgrid Knowledge, December 2, 2022. https://www.microgridknowledge.com/community-microgrids/article/21438504/dominican-republic-villages-seek-to-electrify-with-solar-microgrids-reflecting-global-trend.

Cohn, Lisa. "Here Come the Hurricanes. 15 Island Microgrids Stand Ready." Microgrid Knowledge, June 2, 2023. Accessed August 17, 2023. https://www.microgridknowledge.com/reliability-resilience/article/33006055/island-microgrids-stand-ready-for-another-hurricane-season.

Comunidad Sabana Real, Independencia," May 25 2021, https://transicionenergetica.do/wp-content/uploads/2021/06/21-05-25_-Electrificaci%C3%B3n-Rural-en-Sabana-Real_Descripcion-Proyecto-1.pdf.

Crowell, Chris. "Solar + Storage Project of the Year 2021: Chub Cay Microgrid," Solar Builder Magazine, November 9, 2021, https://solarbuildermag.com/news/2021-project-of-the-year-solar-storage-chub-cay-microgrid/.

Crowley Maritime Corporation. "The Role of Microgrids in a More Sustainable Energy Future." Accessed August 13, 2023. https://www.crowley.com/wp-content/uploads/sites/7/2020/10/Crowley_LNG-White-Paper_The-Role-of-Microgrids.pdf.

CSA Group. "National technical specification for terminology for the decentralized energy industry in Canada." July 2023. CSA TS-117:23

Decentralised Energy Canada. "Caribbean Microgrid Highlights." Accessed August 13, 2023. https://www.deassociation.ca/caribbean-microgrid-highlights-v2.

Delegation of the European Union to Trinidad and Tobago. "Installation of a Solar Park at Piarco International Airport," Delegation of the European Union to Trinidad and Tobago, March 30, 2020. https://www.eeas.europa.eu/delegations/trinidad-and-tobago/installation-solar-park-piarco-international-airport_en?s=156.

EH+. "Proyecto de microrred fotovoltaica avanza en comunidad de Sabana Real", EH+ Periodico Digital, July 25, 2023, https://ehplus.do/proyecto-de-microrred-fotovoltaica-avanza-en-comunidad-de-sabana-real/.

Energy Unit. Energy Buzz Newsletter. Energy Unit Ministry of Communication, Works, Labour & Energy, Government of Montserrat, Vol. 2; Iss. 1, April-June 2021. https://www.gov.ms/wp-content/uploads/2021/06/Energy-Newsletter-Vol.2-Issue-1.pdf.

GCCA+. "Solar farm in Trinidad & Tobago." European Union Delegation to Trinidad & Tobago, The Global Climate Change Alliance Plus, Factsheet Edition, November 2020. https://www.eeas.europa.eu/sites/default/files/factsheet_gcca_aatt_nov20_0.pdf.

Global Industry Analysts. “Global Microgrids Industry.” Published January 2023. Report ID:6460474.

Golden Media. “750 kW Solar Power Grid to Provide Backup for Critical Facilities in Northern Montserrat,” Discover Montserrat, Golden Media LLC., January 26, 2021. https://discovermni.com/2021/01/26/750kw-solar-power-grid-to-provide-backup-for-critical-facilities-in-northern-montserrat/.

Government of the Virgin Islands. “British Virgin Islands Resilient National Energy Transition Strategy,” Government of the Virgin Islands June 2019. https://bvi.gov.vg/pub/BVI_R_NETS_June_2019.pdf.

Guidehouse Insights. "Opportunities in the Caribbean Microgrid Market." Accessed August 13, 2023. https://guidehouseinsights.com/news-and-views/opportunities-in-the-caribbean-microgrid-market.

Guzman, Mayelin Acosta. “Sabana Real tendrá energía en junio,” *Hoy Newspaper*, May 12, 2023, https://hoy.com.do/sabana-real-tendra-energia-en-junio/.

Huang, Siting, Feng Liu, Yulin Li, and Fanyu Zeng. "Integrating Blockchain with Microgrid: A Sustainable Energy Trading Perspective." Sustainability 12, no. 22 (2020): 9746. Accessed August 13, 2023. https://www.mdpi.com/2071-1050/12/22/9746.

Hudson, Gavin. "Monetizing Microgrids: Utilities Are Missing a Unique Opportunity." Utility Dive, July 30, 2019. Accessed August 13, 2023. https://www.utilitydive.com/news/monetizing-microgids-utilities-are-missing-a-unique-opportunity/560277/.

Inter-American Development Bank (IDB). "Greening Value Chains: How Large Companies in Latin America and the Caribbean Can Influence Natural Resource Use and Environmental Impact Management in Their Value Chains." Technical Study. Accessed August 13, 2023. https://publications.iadb.org/publications/english/document/Greening-Value-Chains-How-Large-Companies-in-Latin-America-and-the-Caribbean-Can-Influence-Natural-Resource-Use-and-Environmental-Impact-Management-in-Their-Value-Chains-Technical-Study.pdf.

Inter-American Development Bank. *Sustainable Energy Paths for the Caribbean*. https://publications.iadb.org/publications/english/document/Sustainable_Energy_Paths_for_the_Caribbean.pdf.

International Energy Agency (IEA). "The World's Electricity Systems Must Be Ready to Counter the Growing Climate Threat." Accessed August 13, 2023. https://www.iea.org/commentaries/the-world-s-electricity-systems-must-be-ready-to-counter-the-growing-climate-threat.

International Monetary Fund (IMF). "Strengthening Caribbean Regional Integration." February 4, 2020. Accessed August 13, 2023.

https://www.imf.org/en/News/Articles/2020/02/04/NA020420-Strengthening-Caribbean-Regional-Integration.

International Renewable Energy Agency (IRENA). "Renewable Energy in Latin America and the Caribbean: Towards a Regional Energy Transition." *IRENA Events*, June 2022. https://www.irena.org/events/2022/Jun/Renewable-Energy-in-Latin-America-and-the-Caribbean-Towards-a-Regional-Energy-Transition.

International Renewable Energy Agency (IRENA). "Renewable Energy in Latin America and the Caribbean: Towards a Regional Energy Transition." June 2022. Accessed August 13, 2023. https://www.irena.org/events/2022/Jun/Renewable-Energy-in-Latin-America-and-the-Caribbean-Towards-a-Regional-Energy-Transition.

Ivey Business School. "The Transition to Net Zero: What Are Canadian Companies Committing To?" October 2021. Accessed August 13, 2023. https://www.ivey.uwo.ca/sustainability/news/2021/10/the-transition-to-net-zero-what-are-canadian-companies-committing-to/.

Khan-Labban, Areefa. "ICAO-European Union Joint Assistance Project: Feasibility Study on Renewable Energy Piarco International Airport Trinidad & Tobago," Trinidad & Tobago Civil Aviation Authority. https://www.icao.int/environmental-protection/Documents/2_5_Renewable%20Energy%20Piarco%20International%20Airport%20Trinidad%20and%20Tobago.pdf.

Lewis, Clint T. and Ming-Chien Su. "Climate Change Adaptation and Sectoral Policy Coherence in the Caribbean," Sustainability 13 (July 30, 2021): 8518. Accessed June 2023. https://doi.org/10.3390/su13158518.

McKinsey & Company. "Building Value Chain Resilience with AI." Accessed August 13, 2023. https://www.mckinsey.com/industries/metals-and-mining/our-insights/building-value-chain-resilience-with-ai.

Microgrid Knowledge. "Building a Microgrid That Stands Its Ground in the Storm-Tossed Caribbean." Accessed August 13, 2023. https://www.microgridknowledge.com/editors-choice/article/11427800/building-a-microgrid-that-stands-its-ground-in-the-storm-tossed-caribbean/.

Microgrid Knowledge. "Dominican Republic Villages Seek to Electrify with Solar Microgrids, Reflecting Global Trend." Accessed August 13, 2023. https://www.microgridknowledge.com/community-microgrids/article/21438504/dominican-republic-villages-seek-to-electrify-with-solar-microgrids-reflecting-global-trend.

Ministry of Planning and Development. "Solar Park makes progress at Piarco International Airport," Government of the Republic of Trinidad and Tobago, January 3 2023. https://www.planning.gov.tt/content/solar-park-makes-progress-piarco-international-airport

National Renewable Energy Laboratory (NREL), "Island Energy Snapshots." Office of Energy Efficiency & Renewable Energy, U.S. Department of Energy. November 2020. https://www.energy.gov/eere/island-energy-snapshots DOE/GO-102020-5483

New Energy Events. "Building a Microgrid That Stands Its Ground in the Storm-Tossed Caribbean." Accessed August 13, 2023. https://newenergyevents.com/building-a-microgrid-that-stands-its-ground-in-the-storm-tossed-caribbean/.

Noble, Stephanie M., Martin Mende, Dhruv Grewal, A. Parasuraman. "The Fifth Industrial Revolution: How Harmonious Human–Machine Collaboration is Triggering a Retail and Service [R]evolution." Journal of Retailing, Volume 98, Issue 2, 2022, Pages 199-208, ISSN 0022-4359. https://doi.org/10.1016/j.jretai.2022.04.003.

Presidencia de la Republica Dominicana. "Más de 75 familias beneficiadas con proyecto de electrificación rural en Sabana Real, La Descubierta," *Presidencia de la Republica Dominicana*, December 1, 2021, https://presidencia.gob.do/noticias/mas-de-75-familias-beneficiadas-con-proyecto-de-electrificacion-rural-en-sabana-real-la.

Proyecto Transición Energética. "Actualización Proyecto Piloto Sabana Real," Transforma Boletín Informativo No. 9, 2022, p. 19, https://transicionenergetica.do/2022/12/15/6220-2/ .

Proyecto Transición Energética. "Proyecto Piloto Electrificación Rural Comunidad Sabana Real, Independencia," May 25 2021, https://transicionenergetica.do/wp-content/uploads/2021/06/21-05-25_-Electrificaci%C3%B3n-Rural-en-Sabana-Real_Descripcion-Proyecto-1.pdf.

Rahman, Shaikh M., Ariel Dinar, & Donald Larson. "The incidence and extent of the CDM across developing countries," Environment and Development Economics 21 (January 22, 2016): 415-438. Accessed June 2023. doi: 10.1017/S1355770X15000388.

Ristuccia, Christina, and Isaac Maze-Rothstein. "7 Companies Making Their Mark in Commercial Microgrids." GreenBiz, April 28, 2020. Accessed August 13, 2023. https://www.greenbiz.com/article/7-companies-making-their-mark-commercial-microgrids.

Rocky Mountain Institute (RMI). "Islands, Microgrids, and the Global Energy Transition: Case Study Profiles of Islands and Remote Communities." 2015. Accessed August 13, 2023. https://rmi.org/wp-content/uploads/2017/04/Islands_Microgrid_Profiles_Islands_Global_Remote_Communities_CaseStudy_2015.pdf.

Rocky Mountain Institute. "Mayreau Microgrid Project Accepting Bids," Rocky Mountain Institute Press Release, April 1 2023. https://rmi.org/press-release/press-release-mayreau-microgrid-project-accepting-bids/ .

Rocky Mountain Institute. “Mayreau Microgrid Project Kicks Off,” Rocky Mountain Institute Press Release, April 11 2018. https://rmi.org/press-release/mayreau-microgrid-project-kicks-off/.

Rocky Mountain Institute. “Request for Quotations (RFQ),” Rocky Mountain Institute, April 2022. https://rmi.org/wp-content/uploads/2022/04/geotechnical_study_paraquita_bay_rfq.pdf.

Rocky Mountain Institute. “RFQ for EPC companies: Microgrid in Paraquita Bay, British Virgin Islands,” Rocky Mountain Institute, 2021. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwim5-K1sf2AAxXQJTQIHZfLAzkQFnoECAkQAQ&url=https%3A%2F%2Frmi.org%2Fwp-content%2Fuploads%2F2021%2F12%2FParaquita_Bay_Microgrid_RFQ.docx&usg=AOvVaw16eNH3vtoMA_4CHVjKA5Ro&opi=89978449.

Salas, Erick Burgueño. “Costliest natural disasters based on estimated overall losses in the Caribbean between 2000 and 2022.” Statista (January 2023).

Sheehan, Tierney, and Colm Quinn. “We are Abaco Strong”- The Bahamas Inspiring Resilience at Scale,” Rocky Mountain Institute, May 12, 2023. https://rmi.org/we-are-abaco-strong-the-bahamas-inspiring-resilience-at-scale/ .

Shefchik, Claire. “CDB: Paraquita grid could be regional model,” The BVI Beacon, February 14, 2022. https://www.bvibeacon.com/cdb-paraquita-grid-could-be-regional-model/.

Shirley, Rebekah, and Daniel M. Kammen. "Renewable Energy Policy and Public Preferences: A Californian Case Study." Energy Policy 57 (2013): 641-647. Accessed August 13, 2023. https://gspp.berkeley.edu/assets/uploads/research/pdf/Shirley_Kammen_Energy_Policy_Vol_57.pdf.

Solar Island Energy. "Our Approach." Accessed August 13, 2023. https://solarislandenergy.com/our-approach/.

Spencer, Nekeisha, Solomon Polachek, & Eric Strobl. “How do hurricanes impact scholastic achievement? A Caribbean Perspective,” Nat Hazards 84 (August 1, 2016): 1437-1462. Accessed June 2023. doi: 10.1007/s11069-016-2494-7.

St. Vincent Electricity Services Limited. “Our History,” St. Vincent Electricity Services Limited 2020, https://www.vinlec.com/contents/our-history.

Stone, Laurie. “How the Storm-Ravaged Bahamas Can Be a Model for Resilient Energy,” Rocky Mountain Institute, July 26, 2022, https://rmi.org/how-the-storm-ravaged-bahamas-can-be-a-model-for-resilient-energy/.

Stone, Laurie. “Monteserrat - Halfway on the Road to 100 Percent Renewables,” Rocky Mountain Institute, November 8, 2021. https://rmi.org/monserrat-halfway-on-the-road-to-100-percent-renewables/.

Stone, Laurie. “Siana and Zsaria: Speeding the Caribbean’s Energy Transition,” Rocky Mountain Institute, January 26, 2023. https://rmi.org/siana-and-zsaria-speeding-the-caribbeans-energy-transition/.

Tabuchi, Hiroko. "California, of All Places, Has an Electricity Shortage." The New York Times, May 6, 2022. Accessed August 13, 2023. https://www.nytimes.com/2022/05/06/business/energy-environment/california-electricity-shortage.html.

The BVI Beacon. "19 Firms Apply to Build Microgrid." Accessed August 13, 2023. https://www.bvibeacon.com/19-firms-apply-to-build-microgrid/.

The National Gas Company of Trinidad and Tobago Limited. “Harnessing the Power of Microgrid,” The National Gas Company of Trinidad and Tobago Limited, October 26, 2022. https://media.ngc.co.tt/wp-content/uploads/2022/10/2022-10-26_article_harnessing-the-power-of-microgrids.pdf.

Trinidad and Tobago Guardian. “Minister: Steady progress at Piarco Solar Park,” Government of the Republic of Trinidad and Tobago, Ministry of Planning and Development, March 2023. https://www.planning.gov.tt/content/news-minister-steady-progress-piarco-solar-park.

Vedrine, Betty. “Solar Park Opens at National Stadium,” The Government of the Bahamas, March 20, 2019, https://www.bahamas.gov.bs/wps/portal/public/gov/government/news/solar%20park%20opens%20at%20national%20stadium/!ut/p/b1/vZHbjqJAEIafxQdwoJtD42Uj5_OhQegbggwgIuooivr06ySTbHaTmb3Zma6rSv6qL_U1Q5mMofvy2rXl2B325e69p2LBsbqLMS-5kiZi1kw4jRNszOkheAbyZ4D95GH2z3mdpCxrAhZHMQhZnwPMismMHC7Us9mqmDYCfUsUqzMDcRX0hPib7Kbv5MndzIPTgIySW51GalftaR3vDXLhhKpaUH0IwWngz9MR8kJkSlryppXHpK-W9mPY-Zm9m5rUvajL9GJ5t07rxX5LGx7W09x2bl1b0bTYZF3eN43PbYO1vz4hl41COM9roXtM0GjrsNtXjrEWsgzh8hypYj_7uP2L4_7hbsXQr_XAj8AXej3jMNRM_oyhz_ZICDGEyVi-iLf3o_noH9H2EQK3b4GXABeo8E4UJ_WSHnij5RElsgFJuFhJWNJPd7KlzjgqwWsaJTJWSkVp5L-BPiSLJ3AJRDsR2FjnvhuoC770lIlIgAX4FCH-NFD4LqDuu-HyXSmR35VyhoFFh_NV8NPA__-HFkO79fAyVcML-yLwQBAWAC5EiCACiEm3OX9TWvOm4Ljou3xnKclrEEp8aSnXx6XtDO9iK7nRqHe1Dp3V1lnlHKkH6VKfN8Jxg1BxvoOC7byaZta6zMeqL6Xp4Be70q0jDVJ1njlokgjRsksKiqa67ajuVrIay-f0Gm6GcmPGRp5YbTjaSoh6NYGhxecB7hSZuHkMg-GKEMhUyK2x98YeHwdLD4bqcEcaHrMokuBtNY_paT68ZXuxaWUpn7ewnc2Y45BcHTGSvOZ3uXg2-wWKp8C-/dl4/d5/L2dBISEvZ0FBIS9nQSEh/

Ward, Jasper. “$5 million solar project completed on Ragged Is.”, The Nassau Guardian, August 15, 2022. https://thenassauguardian.com/5-million-solar-project-completed-on-ragged-is/.

Wood, Elisa. “Microgrids Already on the Way to the Bahamas… Just Not Fast Enough,” Microgrid Knowledge, September 10, 2019, https://www.microgridknowledge.com/distributed-energy/article/11429437/microgrids-already-on-their-way-to-the-bahamas8230just-not-fast-enough.

World Bank. "Greening Value Chains: How Large Companies in Latin America and the Caribbean Can Influence Natural Resource Use and Environmental Impact Management in Their Value Chains." Accessed August 13, 2023. https://openknowledge.worldbank.org/handle/10986/16618.

World Bank. *360 Resilience: A Guide to Prepare the Caribbean for a New Generation of Shocks*. World Bank. November 8, 2021. https://www.worldbank.org/en/news/press-release/2021/11/08/-360-resilience-a-guide-to-prepare-the-caribbean-for-a-new-generation-of-shocks.

World Economic Forum. "Climate Change and Electricity: Ensuring Energy Security in Extreme Weather." July 2021. Accessed August 13, 2023. https://www.weforum.org/agenda/2021/07/climate-change-electricity-energy-security-extreme-weather/.

World Economic Forum. "How to Power a Resilient Future Across the Caribbean." *World Economic Forum Agenda*, September 2020. https://www.weforum.org/agenda/2020/09/how-to-power-a-resilient-future-across-the-caribbean.

2. Decentralised Energy Terminology

In partnership with the Standards Council of Canada and Decentralised Energy Canada, CSA Group published the first-of-its-kind technical specification, CSA TS-117. This comprehensive documentation addresses a longstanding need for a standardised vocabulary in the decentralised energy sector, fostering a shared understanding of key terms among industry players and stakeholders.

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Terminology used in this report:

Anti-islanding protection — a protection function or combination of protection functions that prevents distributed energy resources from supplying electricity to an unintentional island.

Battery-based micro-hydropower system — a micro-hydropower system that uses batteries for energy storage, usually in less than 5 kW capacities.

Bioenergy — renewable energy derived from biomass through conversion to biofuel.

Biofuel — fuel derived from biomass.

Biogas — gas resulting from the fermentation or gasification of biomass.

Biomass — renewable energy source in the form of material of biological origin excluding material embedded in geological formations or transformed to fossilised material.

Cogeneration, or Combined heat and power (CHP) — the production of heat that is used for both nonelectrical purposes and the generation of electric energy.

Community energy — the delivery of community-led renewable energy, energy demand reduction, and energy supply projects, whether wholly owned and/or controlled by communities or through a partnership with commercial or public sector partners.

Community energy plan (CEP) — a process that considers energy early in the land use and infrastructure planning process and identifies opportunities to integrate local energy solutions at a building or neighbourhood scale.

Community generation — energy that is distribution network-connected and provides benefits to communities. Community generation allows communities to directly participate in energy projects through full or partial ownership of the projects.

Demand response — all means employed to change the typical electrical power consumption profile of a given area. Changing the power consumption profile aims to meet needs in supply, additional services, and consumption optimisation.

Digitisation — the changing, transforming, or converting of an analogue system into a digital system.

Distributed energy resource (DER) —

- an electricity generation source, storage unit, or charge controller connected to the distribution network at a low or medium voltage level. The DER can include protection, control, and measurement units, and can be aggregated in an energy system.
- a source of electric power, including controllable loads, that is not directly connected to a bulk power transmission system.

Distributed energy resource management system (DERMS) — a platform that helps mostly distribution system operators manage grids that are mainly based on distributed energy resources.

Distributed generation (DG) — electric generation facilities, including electric energy storage in discharge mode, that are connected to a distribution system through a point of common coupling (see Distributed energy resource).

Distributed supervisory control and data acquisition (DSCADA) — a system in which all the connected nodes within the system can exchange inputs and outputs directly with each other without a central supervisory control and data acquisition hub.

Distribution network — electrical components (including but not limited to poles, transformers, disconnects, relays, isolators, and wires) used for the purpose of distributing electrical energy from substations to customers.

Distribution system operator (DSO) — the party operating a distribution network.

Electrical equipment — any apparatus, appliance, device, instrument, fitting, fixture, luminaire, machinery, material, or thing used in or for, or capable of being used in or for, the generation, transformation, transmission, distribution, supply, or utilisation of electric power or energy and, without restricting the generality of the foregoing, includes any assemblage or combination of materials or things that is used, or is capable of being used or adapted, to serve or perform any particular purpose or function when connected to an electrical installation, notwithstanding that any of such materials or things may be mechanical, metallic, or non-electric in origin.

Electricity exchange market — a trading platform that facilitates the process of reaching an agreement between electricity market participants, which can include suppliers, consumers, and wholesalers.

Energy storage — a system capable of storing energy for use at a later time.

Electrical energy storage (EES) — an installation that can absorb electrical energy, store it, and release it for a certain amount of time during which energy conversion processes might be included.

Exporting — injecting power into the distribution system through the point of common coupling.

Flood hazard zone — a spatially delineated area designated in accordance with the National Building Code of Canada or applicable local legislation as being subjected to a flood hazard.

Fuel cell system — a system consisting of one or more fuel cells and associated equipment that produces usable electricity.

Generating plant, or Generating station — a group of generating units, including auxiliaries, connected to one point of connection.

Generation facility — a facility for generating electricity or providing ancillary services other than ancillary services provided by a transmitter or distributor through the operation of a transmission or distribution system, and includes any structures, equipment, or other things used for that purpose.

Generation forecast — a forecast of the expected production of the distributed energy resources in the microgrid.

Home energy management system (HEMS) — a technological platform that allows users to monitor energy use, generation, and storage at a residence, and to control and/or automate energy use according to occupant preferences.

Hydrokinetic power system — a system operating as an interconnected or stand-alone system and consisting of one or more hydrokinetic turbines that convert the kinetic energy of flowing water into electrical energy.

Interconnection — the result of the process of electrically connecting a distributed energy resource system in parallel to a distribution network.

Distributed energy interconnection — the result of the process of connecting distributed energy resource systems in parallel to distribution networks.

Interconnection system — the collection of interconnection equipment and functions used to interconnect (a) DER unit(s) to the point of DER connection.

Interruptible load — a load of particular consumers that, according to contract, can be disconnected by the supply undertaking for a limited period of time.

Inverter — power conversion equipment consisting of an electronic static converter that changes DC electrical power to AC electrical power.

Island —

1) that portion of a distribution system that is energised by one or more distributed energy resources through their point of common coupling(s) while that portion is separated electrically from the rest of the distribution system.
2) the condition in which a portion of the distribution system is energised by one or more distributed energy resources through their point of common coupling(s) while that portion is separated electrically from the rest of the distribution system.

Intentional island — an island that results from planned action(s) of automatic protections or deliberate action(s) by the responsible network operator, or both, in order to keep supplying electrical energy to a section of an electric power system.

Unintentional island — an island that is not anticipated by the relevant network operator.

Isolated microgrid, or Stand-alone microgrid — a group of interconnected loads and distributed energy resources forming a local electric power system at distribution voltage levels that is not capable of being connected to a wider electric power system.

Load forecast — an estimate of the expected load of a network at a given future date.

Load profile — the curve representing supplied electric power against time of occurrence to illustrate the variance in a load during a given time interval.

Lockout — the placement of a lock on an energy-isolating device in accordance with an established procedure.

Main switch — a switch installed as close as possible to the point of connection for protection against internal faults and disconnection of the whole plant from the distribution network.

Microgrid — a group of interconnected loads and distributed energy resources with defined electrical boundaries that acts as a single controllable entity and can operate in both grid-connected and island mode.

Microgrid energy management system — a system operating and controlling energy resources and loads of the microgrid.

Micro-hydropower system — a system with a rated output of 100 kW or less and operating as an interconnected or stand-alone system while consisting of one or more hydraulic turbines that convert energy derived from flowing and falling water primarily by utilising the available head difference.

Non-isolated microgrid — a group of interconnected loads and distributed energy resources with defined electrical boundaries forming a local electric power system at distribution voltage levels that can be connected to a wider electric power system.

Normal operation — the operation of a program or activity without significant changes that would impair its ability to meet its objectives.

Penetration levels (high/low) — the aggregate capacity of distributed energy resources connecting to a particular feeder or section of a distribution system. This Document intentionally uses qualitative DER penetration level qualifiers (high/low penetration). The wires owner will define the aggregate capacity for each section of their distribution system that determines whether the penetration level is either high or low.

Point of distributed energy resource connection — the point where the distributed energy resource is connected to a different system. This can be the same as the point of common coupling or, in the case of a stand-alone system, it can be the point at which the stand-alone network or load is connected to the distributed energy resource.

Power producer — a legal entity responsible for a distributed energy resources system that is interconnected to the local distribution system for the purpose of generating electric power.

Power quality — characteristics of the electric current, voltage, and frequencies at a given point in an electric power system that are evaluated against a set of reference technical parameters.

Power system stability — the capability of a power system to regain a steady state, characterised by the synchronous operation of the generators after a disturbance because of, as an example, a variation of power or an impedance.

Protection scheme — protection functions (including associated sensors, relaying, and power supplies) intended to protect a distribution system or interconnection equipment.

Protection system — an arrangement of one or more pieces of protection equipment and other devices intended to perform one or more specified protection functions.

Reliability — in an electric power system, the probability that the electric power system can perform a required function under given conditions for a given time interval.

Reliability of protection — the probability that a protection can perform a required function under given conditions for a given time interval.

Renewable energy — primary energy with a source that is constantly replenished and will not become depleted.

Renewable energy system — all interconnected equipment, up to and including the system disconnecting means, that converts renewable energy into electrical energy.

Reverse current — the flow of direct electric current in a reverse direction or of alternating current in phase opposition to normal.

Security — the ability of an electric power system to operate in such a way that credible events do not give rise to loss of load, stresses of system components beyond their ratings, bus voltages or system frequency outside tolerances, instability, voltage collapse, or cascading.

Security of protection — the probability of a protection not having an unwanted operation under given conditions for a given time interval.

Selectivity of protection — the ability of a protection to identify the faulty section and/or phase(s) of a power system.

Solar photovoltaic system — a renewable energy system that converts solar energy into electrical energy.

Stability, Electric power system — the capability of a power system to regain or to retain a steady-state condition, characterised by the synchronous operation of the generators and/or a steady acceptable quality of the electricity supply after a disturbance due to, as an example, a variation of power or an impedance.

Stability, Microgrid — the capability of a microgrid to regain a steady state after being subjected to a disturbance without involuntary load shedding.

Stand-alone system — a system that supplies power independently of a supply authority's electrical production and distribution network.

Supply authority — any person, firm, corporation, company, commission, or other organisation responsible for an electrical power distribution network that connects to a consumer's service.

System operator — any party responsible for safe and reliable operation of a part of the electric power system in a certain area and for connection to other parts of the electric power system.

Transfer trip — a remote signal directed from an upstream device to command the interconnection system to disconnect from the distribution system.

Transmission line — a supply line used for transmitting bulk electrical energy between power stations, switching stations, or substations.

Trip — a disconnection from the distribution system.

Virtual power plants — a group of energy resources that are generally decentralised and coordinated to provide services (i.e., power and/or energy) to the network by behaving in whole or in part like a power plant.

Wind turbine — mechanical equipment that converts the kinetic energy of wind into electrical energy and includes all electrical components and circuits within the wind turbine structure.

Wind turbine generator (WTG) system — a system that converts the kinetic energy of wind into electrical energy.

Wires owner — the legal entity responsible for the distribution system.

3. Report Context

Decentralised Energy Canada (DEC) and the Rocky Mountain Institute (RMI) are delivering a one-year program to accelerate collaboration and trade between Canada and the Caribbean specifically related to microgrids. This initiative is supported by a contribution from Global Affairs Canada's CanExport Associations program.

DEC is a respected and essential national, nonprofit, industry association committed to the responsible development of decentralised energy. The association was established in 2003 and has since built a network of over 10,000 subscribers and reaches more than 250,000 industry stakeholders through collaboration agreements with strategic partners. DEC's business model is unique to industry associations in that it secures more than half of its revenue from the private sector to support a balanced portfolio of programs that support domestic market growth and export development capacity of decentralised energy innovations. DEC's vision is a sustainable, resilient, and affordable energy future supported by decentralised energy solutions.

RMI is an independent, nonpartisan, nonprofit organisation working to accelerate the clean energy transition. It was founded in 1982 with a mission to transform the global energy system to secure a clean, prosperous, zero-carbon future for all. RMI's Island Energy Program works with governments, utilities, regulators, and civil society in 20 Caribbean Island Nations to accelerate their transition to cleaner, resilient and affordable energy. They have supported the implementation of over 24 projects totalling over 70 megawatts renewable power.

This one-year program includes four activities:

1. 2023 Caribbean Microgrids Market Overview
2. Export Primer and Virtual B2B Matchmaking

3. Caribbean Mission to Canada in Fall 2023 (Decentralised Energy Forum)
4. Canadian Mission to the Caribbean in Spring 2024

The **Market Overview** provides valuable information regarding the current state of energy in the CARICOM nations and the role that microgrids can play in a sustainable, resilient, and affordable energy future. The overview also draws attention to some of the shared opportunities and challenges in Canada and the Caribbean in terms of energy security and accessibility. Important definitions used in the industry are provided along with examples of microgrid project developments in the Caribbean. A high-level report overview video can be found here.

The **Export Primer** will assist Canadian companies with the development of their market entry or business growth plans in the Caribbean. A cohort of high potential Canadian exporters with commercially proven microgrid innovations will have strengthened capacity for exporting to the Caribbean and an enhanced value proposition regarding how their product or service supports sustainable development goals for the region. This activity culminates with a virtual business to business matchmaking session between Canadian companies with export interest and Caribbean stakeholders involved with microgrid developments.

In November 2023, a congregation from the Caribbean will attend the **Decentralised Energy Forum** in Chateau Lake Louise in Alberta. A mix of government representatives, facility managers in hospitality and healthcare, and community planners will receive support from this program to attend and participate in the forum. Stakeholders will share knowledge and expertise regarding microgrid adoption in the Caribbean and challenges that must be addressed for microgrids to reach their full potential.

In spring of 2024 a Canadian team of microgrid product and service providers will be supported by this program to attend and participate in a business development **Mission to the Caribbean**. This activity will leverage the other activities allowing for multiple opportunities for business partnerships to develop.

4. Data Matrix

STATE // TERRITORY	GEOGRAPHICAL & POPULATION			THE CURRENT SITUATION				
	Population CARICOM	Size (km2)	Extreme Weather &	Energy Cost				National Renewable Energy
	19,360,163	464,353		Residential (USD/kWh)	Commercial	Industrial	Notes	https://www.energy.gov/eere/island-
Antigua and Barbuda©	98,728	440	Hurricane Irma: $222 M USD	.14-.15	.14-.17		Residential: Minimum Charge	
Bahamas© 13,880 km2 (31) 700	393,500	13,880	Hurrican Matthew 2015 (55).	$0.32	$0.37	$0.00	Data dates back to 2015 (31)	
Barbados©	287,708	430	Multiple Category 4 and 5	0.25	0.28	0.25	(51)	
Belize©	430,191	22,970		.11-.2	0.2	.13-.23	USD/ kWh Social (60kWh or less	
Dominica©	72,376	750		.21-.25	.23-.26	0.22	Average Electricity Rates	
Grenada©	113,135	340		0.32	.3-.32	.28-.3	USD/kWh Residential: $0.32;	
Guyana©	790,329	214,970		0.2	0.27	0.24	Average Electricity Rates	
Haiti©	11,905,897	27,750		0.13	0.14	0.14	Average Maximum Electricity	
Jamaica©	2,736,800	11,000		0.28	.21-.32	0.2	USD/kWh Residential: $0.28;	
Montserrat ©	4,429	102		0.39-0.57	0.42-0.57	0.39-0.54	CCREEE ERC 2021	
St. Lucia©	182,279	620		0.28	.32-.34	0.34	Average Electricity Rates	
St. Kitts & Nevis©	53,546	260		0.26	0.28	0.28	Average Electricity Rates	
St. Vincent and the	110,295	389		0.19	.2-.21	0.16	Average Electricity Rates	
Suriname©	591,798	163,820		0.04	.05-.07	0.07	Average Electricity Rates	
Trinidad and Tobago©	1,367,559	5,128		0.05	0.06	0.03	Electricity is subsidised (25).	
Anguilla©	17,422	91		0.2	0.23	0.16	Average Electricity Rates	
Bermuda©	64,000	53		.14-.38	.25-.35		BELCO https://belco.bm/know-	
British Virgin Islands©	29,802	150		0.24	0.23	0.19	Average Electricity Rates	
Cayman Islands© (self	69,000	260		0.3	0.33	0.31	Average Electricity Rates	
Turks & Caicos Islands©	41,369	950		0.26	.22-.27		Average Electricity Rates	

STATE // TERRITORY	CCREEE - CARICOM Energy Report Cards 2021					
	Installed Capacity (MW)	RE Installed Capacity Share (%)	Peak Demand (MW)	Total Generation (GWh)	T&D Losses	**Energy Consumption Patterns**
	7031.7	**13.22%**	**3629.17**	**23,135.04**		
Antigua and Barbuda©	82.2	14.84%	56.2	371.16	11.72%	Energy consumption per capita
Bahamas© 13,880 km2 (31) 700	1300.2	0.46%	245	1,663.65	13.00%	Energy consumption per capita:
Barbados©	319	21.00%	157	923.65	5.85%	Energy consumption per capita
Belize©	192.82	43.26%	103.46	668.44	12.80%	Energy consumption per capita
Dominica©	27.16	25.99%	16.39	100.78	8.10%	Energy consumption per capita
Grenada©	55.73	4.56%	32.23	228.91	6.63%	Energy consumption per capita
Guyana©	348.56	16.00%	124.5	902.00	25.00%	Energy consumption per capita
Haiti©	361.61	19.27%	248	2,199.00	50.00%	Energy consumption per capita
Jamaica©	1049.9	17.62%	632	4,304.00	28.40%	Energy consumption per capita
Montserrat ©	8.09	12.36%	2.15	0.01	8.52	Electricity Consumption by Sector:
St. Lucia©	93.07	5.02%	31.08	371.60	6.28%	Energy consumption per capita
St. Kitts & Nevis©	64.93	3.74%	36.03	0.29	16.60%	Energy consumption per capita
St. Vincent and the	52.46	17.88%	24.59	153.00	6.67%	Energy consumption per capita
Suriname©	443.58	44.57%	229	668.44	11.54%	Energy consumption per capita
Trinidad and Tobago©	2117.99	0.50%	1370	8,804.50	6.10%	Total primary energy consumption
Anguilla©	26	8.00%	15.54	0.10	9.40%	--
Bermuda©	172	0.00%	122.8	650.00	5.00%	Energy consumption per capita
British Virgin Islands©	57.4	1.70%	34	210.20	13.00%	Electricity Consumption by Sector:
Cayman Islands© (self	172	6.50%	113.5	678.80	5.40%	Energy consumption per capita
Turks & Caicos Islands©	87	1.20%	35.7	236.50	5.60%	Energy Consumption by Sector:

STATE // TERRITORY	TRANSITION DRIVERS DRIVING MICROGRID DEVELOPMENT							
	General Energy Sector Info	Policy		Economics				Industry transformation
		KEY FIGURES	ENERGY POLICY	GDP PER	GDP Total	GNI (Gross	Other	
Antigua and Barbuda©	Electricity Generation Mix = 93% fossil fuels; 7%	Government Institution for	Targets: 15% by 2030 (2011		$1.61 Bn USD	$15,890 USD	Share of GDP Spent on Imports 47.8% Fuel Imports 4.5% Urban Population Percentage 24.50%	ntigua and Barbuda: "one of
Bahamas© 13,880 km2 (31) 700	Mostly reliant on imported fossil fuels. Energy	Ministry of the	Policy and Regulatory	$32,000 USD	$11.4 Bn (2015)			"Moderate potential for
Barbados©	Reliant on Mainly fossil fuel resources. Heavy fuel	Government Institution for	Target of 100% energy from RE		$5.145 Bn USD	$15,410 USD (51)	Share of GDP Spent on Imports 40.9% Fuel Imports 6% Urban Population Percentage 31.2%	
Belize©	Electricity Generation Mix = Hydropower 38%;	Government Institution for	Conditional target: 85% by 2030;		$1.87 Bn USD	$4,470 USD (35)	Share of GDP Spent on Imports 58% Fuel Imports 1.5% Urban Population Percentage 46%	
Dominica©	Electricity Generation Mix: Diesel 63%;	Government Institution for	Existing policy and regulatory		$551 M USD (39)	$7,090 USD (39)	Share of GDP Spent on Imports 65.1% Fuel Imports 17.7% Urban Population Percentage 71.1%	
Grenada©	Electricity Generation Mix: Diesel 98.5%; RE 1.5%	Government Institution for	Existing Policy and Regulatory		$1.186 Bn US	$9,650 USD (38)	Share of GDP Spent on Imports 55.2% Fuel Imports 6% Urban Population Percentage 36.5%	
Guyana©	Electricity Generation Mix: Heavy Fuel Oil &	Government Institution for	Existing Policy and Regulatory		$3.9 Bn USD	$4,991 USD (40)	Share of GDP Spent on Imports 47.1% Fuel Imports 13.2% Urban Population Percentage 26.8%	uyana interior has some
Haiti©	Generation mix: Fossil fuels 93%; Renewables 7%	Government Institution for	Existing Policy and Regulatory		$9.66 Bn USD	$1,880 USD (41)	Share of GDP Spent on Imports 58.5% Fuel Imports 9.8% Urban Population Percentage 57.1%	
Jamaica©	Electricity Generation Mix: Fossil Fuels 89%	GPS Government	Target 20% renewable		$15.71 Bn USD	$4,970 USD (37)	Share of GDP Spent on Imports 51% Fuel Imports 7.4% Urban Population Percentage 56%	
Montserrat ©	Electricity Generation Mix (2018): Fuel oil 100%	Government Institution for	Existing Policy and Regulatory	$12,754 USD (42)	$63.7 M USD		Share of GDP Spent on Imports 88.0% Fuel Imports 2.4% Urban Population Percentage 9.1%	
St. Lucia©	Electricity Generation Mix: Diesel 99%; Solar 1%	Government Institution for	Existing Policy and Regulatory		$1.92 Bn USD	$9,560 USD (43)	Share of GDP Spent on Imports 43% Fuel Imports 4.9% Urban Population Percentage 18.8%	
St. Kitts & Nevis©	Electricity Generation Mix : Diesel 95%; Wind 3%;	Government Institution for	Existing Policy and Regulatory		$1.01 Bn USD	$18,340 USD (44)		
St. Vincent and the	Electricity Generation Mix: Diesel 81%;	Government Institution for	Existing Policy and Regulatory		$8.1 M USD (45)	$7,340 USD (45)	Share of GDP Spent on Imports 55% Fuel Imports 6.2% Urban Population Percentage 53%	
Suriname©	Electricity generation mix: Hydropower 59.6%;	Government Institutions	Existing policy and regulatory		$3.6 Bn USD	$5,210 USD (46)	Share of GDP Spent on Imports 44% Fuel Imports 4% Urban Population Percentage 66%	
Trinidad and Tobago©	The largest oil and natural gas producer in	BP Trinidad and Tobago	Largest oil and natural gas		$23.8 Bn USD	$15,950 USD	Share of GDP Spent on Imports 51% Fuel Imports 4.7% Urban Population Percentage 53.2%	urrent microgrid projects: 0.5
Anguilla©	Generation mix: Fossil fuels 96.2%; Solar PV 3.8%	Government Institution for	Existing policy and regulatory	$12,200 USD	$280.93 M USD		Share of GDP Spent on Total Imports 28% Fuel Imports 4% Urban Population Percentage 100%	
Bermuda©								
British Virgin Islands©	Electricity Generation Mix: Diesel 99.95 %; Wind	Government Institution for	Existing Policy and Regulatory	$48,511 (48)	$1.5 Bn USD (48)		Share of GDP Spent on Imports 29% Fuel Imports 8% Urban Population Percentage 48.5%	
Cayman Islands© (self	Electricity Generation Mix: Diesel 97.4%; Solar	Government Authority	Existing policy and regulatory		$5.14 Bn USD	$47,140 (USD)	Share of GDP Spent on Imports 15% Fuel Imports 5% Urban Population Percentage 100%	
Turks & Caicos Islands©	Generation mix: Diesel 99.8%; Solar 0.2% (50).	Government Institution for	Existing Policy and Regulatory		$1.022 Bn USD	$24,580 USD	Share of GDP Spent on Imports 47% Fuel Imports 8.5% Urban Population Percentage 94%	