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INTERNATIONAL CENTER
ON SMALL HYDROPOWER

World Small Hydropower Development Report 2022

Caribbean

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Table of Content

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Caribbean

Countries: Cuba, Dominica, Dominican Republic, Grenada, Guadeloupe, Haiti, Jamaica, Puerto Rico, Saint Lucia, Saint Vincent and the Grenadines

INTRODUCTION TO THE REGION

The electricity sectors of countries in the Caribbean are heavily reliant on thermal power for electricity generation, with renewable energy sources (RES) playing a supplementary role. Compared to other countries in the region, both the Dominican Republic and Guadeloupe have a highly diversified energy mix, although fossil fuels still predominate. Alongside wind power, solar power and hydropower, RES in the region are represented by biomass and geothermal power plants.

The role of hydropower in the region is limited due to environmental and economic factors. Only Cuba, the Dominican Republic and Haiti employ large hydropower plants, while Grenada and Saint Lucia have no hydropower capacity of any kind. In other countries in the region, all existing hydropower capacities are represented by small hydropower (SHP).

Access to electricity is at or near 100 per cent across most countries in the region with the exception of Haiti. However, seasonal extreme weather in the form of hurricanes and associated floods frequently interfere with power grids and plant infrastructure across the region, causing major disruptions to electricity access. Earthquakes have also caused widespread damage to electricity infrastructure, particularly in Haiti and Puerto Rico.

The role of the state in the electricity sectors of countries in the Caribbean varies significantly. At one end, the electricity sector of Cuba is fully state-owned. In Guadeloupe the sector is dominated by a French company where the Government of France has a controlling stake. In Saint Vincent and the Grenadines, a state-owned company operates the electricity sector across most of the country with the exception of one island, and the electricity sector of Haiti is also dominated by a state-owned company. In Puerto Rico, a state-owned company controls the largest share of generation assets, while transmission and distribution have recently been privatized. In the Dominican Republic, the electricity sector has a significant private sector and state involvement, although state-owned entities control the transmission grid and all hydropower assets. In Dominica, Grenada, Saint Lucia and Jamaica, the electricity sectors have been largely privatized.

An overview of the electricity sectors of the countries in the region is provided in Table 1.

Table 1. **Overview of the Caribbean**

Country	*Total population (million people)*	*Electricity access, total (%)*	*Electricity access, rural (%)*	*Total installed capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower installed capacity (MW)*	*Hydropower generation (GWh/year)*
Cuba	11	100	100	6,508	20,700	64	125
Dominica	0.1	100	100	27	97	7	19
Dominican Republic	10	100	98	4,921	18,688	623	1,245
Grenada	0.1	95	N/A	52	223	0	0
Guadeloupe	0.4	100	100	556	1,689	11	25
Haiti	11	45	1	294	2,199	61	N/A
Jamaica	3	94	91	1,168	4,430	31	155
Puerto Rico	3	100	100	5,839	16	N/A	N/A
Saint Lucia	0.2	99	N/A	92	368	0	0
Saint Vincent and the Grenadines	0.1	100	100	54	151	6	22
Total	-	-	-	**19,511**	-	**802**	-

Source: *WSHPDR 2022*[1]

Note: Data in the table are based on data contained in individual country chapters of the WSHPDR 2022; years may vary.

REGIONAL SMALL HYDROPOWER OVERVIEW

The most commonly-used official definition of SHP in the Caribbean is up to 10 MW, and is adhered to by Dominica, the Dominican Republic, Guadeloupe, and Saint Vincent and the Grenadines. In other countries of the Caribbean, no official SHP definition exists. In Jamaica, which lacks an official definition of SHP, the up to 10 MW definition is commonly used by industry professionals, while in Cuba, the up to 5 MW definition established by the Latin American Organization of Energy (OLADE) is used on an unofficial basis.

A comparison of installed and potential SHP capacities in the region is provided in Table 2.

Table 2. **Small Hydropower Capacities by Country in the Caribbean (MW)**

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed capacity (≤10 MW)*	*Potential capacity (≤10 MW)*
Cuba	N/A	N/A	N/A	21.0	77.0
Dominica	Up to 10 MW	6.6	N/A	6.6	6.6*
Dominican Republic	Up to 10 MW	59.7	N/A	59.7	59.7*
Grenada	N/A	N/A	N/A	0.0	7.0
Guadeloupe	Up to 10 MW	11.6	33.0	**11.6**	33.0
Haiti	N/A	N/A	N/A	6.8	37.6
Jamaica	N/A	N/A	N/A	30.6	76.2
Puerto Rico	N/A	N/A	N/A	39.3	43.9
Saint Lucia	N/A	N/A	N/A	0.0	2.7
Saint Vincent and the Grenadines	Up to 10 MW	5.7	7.5	5.7	7.5
Total	-	-	-	**181.4**	**351.1**

Source: *WSHPDR 2022*[1]

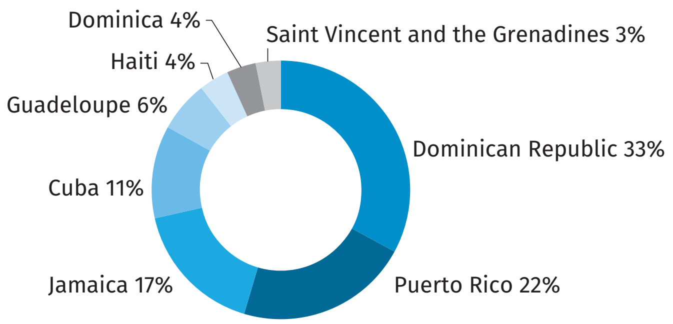
Note: *Based on installed capacity.

The total installed capacity of SHP of up to 10 MW in the Caribbean is 181.4 MW, while estimated potential capacity is 351.1 MW. Relative to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity increased by 2 per cent, largely due to a nearly two-fold increase in the installed SHP capacity of Jamaica. Meanwhile, the installed capacities of several countries including Cuba, Haiti, Puerto Rico, and Saint Vincent and the Grenadines have been revised downwards on the basis of more accurate data. The total potential SHP capacity of the region increased by 18 per cent as a result of updated feasibility studies of potential sites as well as a reassessment of available data.

SHP fills an important niche in the energy mix of the Caribbean region, in part because the geographical and hydrological characteristics of many island countries and the importance of tourism in the region put constraints on the use of large hydropower. SHP accounts for all installed hydropower capacity in Dominica, Guadeloupe, Jamaica, Puerto Rico, and Saint Vincent and the Grenadines. In Cuba approximately a third of all installed hydropower capacity consists of SHP. At the same time, recent development in the SHP sector in the Caribbean has been very limited and further SHP development also faces significant barriers. A major reason for this is the high variability in rainfall and runoff typical for the region and the susceptibility of SHP to extreme weather events, and the consequent focus of many Caribbean countries on other RES.

The national share of regional installed capacity for SHP of up to 10 MW by country is displayed in Figure 1, while the share of total SHP potential utilized by countries in the region is displayed in Figure 2.

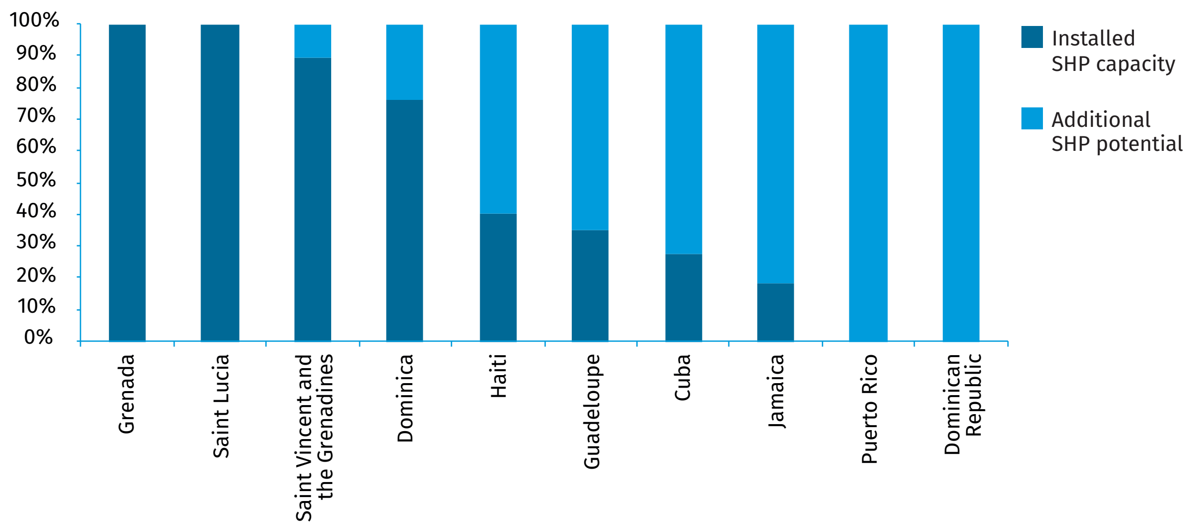
Figure 1. **Share of Regional Installed Capacity of Small Hydropower up to 10 MW by Country in the Caribbean (%)**



Source: *WSHPDR 2022*[1]

Note: Saint Lucia and Grenada not included due to lack of SHP.

Figure 2. **Utilized Small Hydropower Potential up to 10 MW by Country in the Caribbean (%)**



Source: *WSHPDR 2022*[1]

Note: No estimate of potential capacity is available for Dominica and the Dominican Republic, therefore SHP potential in these countries is assumed to be fully utilized.

Cuba has an installed capacity of 21 MW for SHP up to 10 MW, while potential capacity is estimated at 77 MW, indicating that 27 per cent has been developed. Cuba has over 170 SHP plants, of which 32 are currently non-operational due to water supply issues or disrepair. The most recent new SHP plant was commissioned in 2018, while another plant was refurbished in 2019. There were two additional SHP projects under construction as of 2021.

There are three SHP plants of up to 10 MW in **Dominica**, with a total installed capacity of 6.64 MW. The potential capacity of Dominica has not been assessed, so all known capacity is fully developed. One of the SHP plants in the country has been out of operation since 2017 as a result of hurricane damage, and the bidding process for its rehabilitation was launched in early 2022.

The installed capacity of SHP of up to 10 MW in the **Dominican Republic** is 59.7 MW provided by 16 state-owned SHP plants equipped with 22 individual power blocks, and 60 community-owned micro-hydropower plants. There is no reliable estimate of SHP potential in the country, thus, all known potential is considered fully developed. Recent SHP development in the country has been mainly carried out with the support of the Global Environmental Facility (GEF) Small Grants Programme and has focused on the construction of micro-scale plants for the benefit of rural communities. Ten additional micro-scale SHP projects are under construction.

Grenada has no hydropower capacity of any kind. The potential capacity of SHP up to 10 MW is estimated at 7 MW, although the estimate is based on a study conducted in 1981. Several SHP projects have been initiated in recent years but have not been completed and their current status is unknown.

Guadeloupe has a total installed capacity of 11.6 MW for SHP of up to 10 MW, provided by 16 plants. The potential SHP capacity is estimated at 33 MW, indicating that 35 per cent has been developed. However, the development of remaining untapped potential capacities is constrained by environmental considerations and the location of many potential sites inside protected areas. No new SHP construction has taken place in the country since 2016.

The installed capacity of SHP up to 10 MW in **Haiti** is 6.81 MW, provided by eight plants, while potential capacity is estimated at 37.6 MW, indicating that 18 per cent has been developed. No new SHP construction has taken place in the country in recent years and installed capacity has gradually decreased due to ageing equipment and lack of maintenance. Thirty-six potential SHP sites have been identified in the country.

Jamaica has an installed capacity of 30.6 MW for SHP of up to 10 MW, provided by eight SHP plants. The potential capacity for SHP of up to 10 MW is estimated at 76.2 MW, indicating that 40 per cent has been developed. The country's SHP fleet is fairly old and no new additions have been made since 2014, with the recent reported increase in installed capacity being a result of the inclusion of previously excluded plants. Thirteen potential SHP sites have been identified and the country has explicitly adopted a policy of exploring options for SHP construction at locations with the potential to host large hydropower plants.

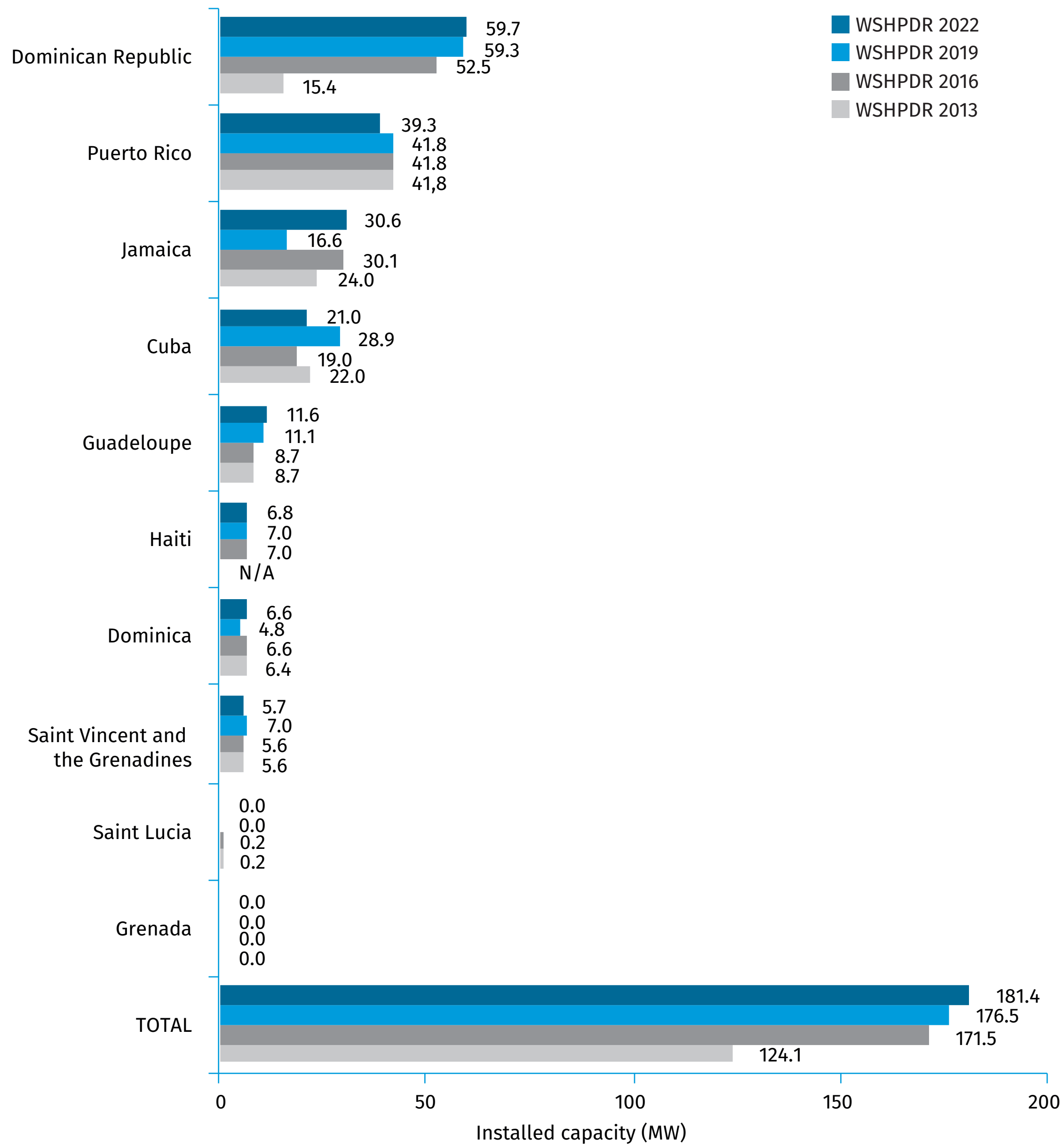
The installed capacity of SHP of up to 10 MW in **Puerto Rico** is 39.3 MW, while potential is estimated at 43.9 MW, indicating that 89 per cent has been developed. There are seven operational SHP plants in the country, although with four of these plants inactive as of 2021, the available capacity has been reduced to 23.8 MW. The main potential opportunities for further SHP development are in micro-scale hydropower projects, as other potential hydropower sites have been largely developed.

Saint Lucia has no hydropower capacity of any kind, as the country's only formerly-operational mini-hydropower plant is in a state of severe disrepair following damage from extreme weather. A potential capacity of 2.68 MW has been identified in previous studies, but there are no ongoing SHP projects in the country or any specific plans for the development of the SHP sector.

In **Saint Vincent and the Grenadines**, the installed capacity of SHP of up to 10 MW is 5.7 MW, while estimated potential capacity is 7.5 MW, indicating that 76 per cent has been developed. There are three SHP plants in the country, but their available capacity fluctuates considerably during the dry season. Refurbishment of two plants was carried out in 2016 and 2018. There are proposals for the construction of an additional SHP plant of 1.2 MW, but no concrete progress has been made.

Changes in the installed SHP capacities of the countries in the region compared to the previous editions of the *WSHPDR* are displayed in Figure 3.

Figure 3. **Change in Installed Capacity of Small Hydropower up to 10 MW from *WSHPDR 2013* to *WSHPDR 2022* by Country in the Caribbean (MW)**



Source: *WSHPDR 2022,*[1] *WSHPDR 2013,*[2] *WSHPDR 2016,*[3] *WSHPDR 2019*[4]

Climate Change and Small Hydropower

The region experiences increased winter precipitation and decreased summer precipitation during the El Niño Southern Oscillation (ENSO) phase. These seasonal differences are expected to become even more pronounced as a result of climate change. The increase in frequency and intensity of extreme events exposes SHP infrastructure to damage.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The barriers to SHP development in **Cuba** include a lack of technical capacity in planning SHP projects and the manufacture of necessary components, limited financial resources and low utilization of existing capacities due to environmental limitations. However, a substantial share of the country's SHP potential remains untapped and government policies are supportive of development in the sector, particularly with regard to foreign investment.

The main barriers to SHP development in **Dominica** include a lack of incentives, a lack of data on SHP potential, issues with land acquisition from private owners and limitations on hydropower development in general due to the importance of eco-tourism in the country. Additionally, the Government has been exploring geothermal power as a prospective RES and has shown comparatively little interest in additional SHP development. However, geothermal power projects are considered to have a higher development cost relative to SHP and it is possible that SHP development will be prioritized again in the future, given the country's experience with this form of renewable energy.

SHP development in the **Dominican Republic** faces a number of challenges including increasing impacts from climate change, which affect water supply and cause damage to SHP infrastructure, a lack of data on SHP potential, lengthy administrative procedures and lack of private sector engagement. However, some studies on the potential of specific SHP sites are available. The SHP sector in the country is well-organized and can lean on decades of experience and local expertise, as well as take advantage of established international financing opportunities. The active development of micro-scale hydropower is expected to continue into the foreseeable future.

In **Grenada**, the lack of interest in SHP on the part of the Government is one of the main barriers to SHP development in the country, along with the lack of up-to-date studies of SHP potential. However, the untapped SHP potential could serve as an additional source of renewable energy to meet the country's declared clean energy goals and reduce dependence on fossil fuels.

The main obstacle to SHP development in **Guadeloupe** are the environmental restrictions that constrain the implementation of additional projects. The country has consequently focused on the development of other RES, in particular solar power, wind power and geothermal power. One possible avenue for further SHP development in the country that would avoid environmental impacts is the optimization of exiting SHP capacities.

SHP development in **Haiti** is hampered by a lack of a legal framework for private investment in the energy sector as well as a lack of coordination between government agencies and ministries, in addition to a lack of funds and limited reach of the country's transmission grid. However, much of the country's identified SHP potential remains untapped and represents an important potential source for electricity generation in a country with the region's lowest rate of electricity access.

Barriers to SHP development in **Jamaica** include the high cost and perceived complexity of construction, institutional barriers and hydrological variability. At the same time, the country possesses considerable untapped SHP potential and the Government's interest in SHP as opposed to large hydropower is a potential driver of future SHP development, both in terms of new construction and modernization of existing capacities.

The main barrier to further SHP development in **Puerto Rico** is the high degree of utilization of the country's existing potential SHP capacities, leaving few remaining undeveloped sites. Severe weather and water shortages are also important barriers. The main opportunities for SHP development in the country lie in micro-scale projects and the refurbishment of existing SHP plants, which has been identified as a priority direction by a government study in 2021. An additional enabler is the availability of support for RES in the form of subsidies.

Barriers to SHP development in **Saint Lucia** include the extremely limited SHP potential and the lack of funding opportunities specifically aimed at SHP projects. However, SHP could serve as an additional source of renewable energy and reduce the country's dependence on fossil fuels if efforts were directed at repairing the existing damaged mini-hydropower plant and develop identified potential sites.

The main barrier to SHP development in **Saint Vincent and the Grenadines** is the variability of river flow throughout the year that complicates the implementation of new SHP projects and also reduces the available capacity of existing plants. Very little SHP potential exists on the country's smaller islands and plans for the development of RES have focused on solar power and geothermal power. At the same time, all RES projects including SHP have access to feed-in tariffs (FITs) and financing for renewable energy development in the country is Available at international institutions including the GEF, the World Bank, the International Renewable Energy Agency and others.

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Cuba

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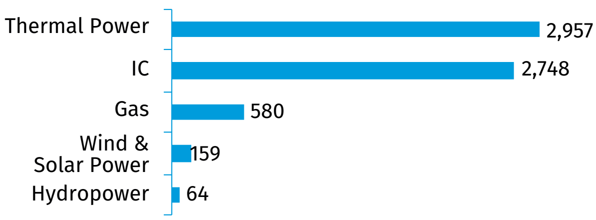
KEY FACTS

Population	11,193,470 (2019)[1]
Area	109,884.01 km^2 [2]
Topography	Approximately a quarter of the territory of Cuba is mountainous with hills dotted across the island, alternating with plains, and four main mountain ranges: the Guamuhaya in the centre (also known as mountains of the Escambray), the Guaniguanico in the west, the Nipe-Sagua-Baracoa in the north-east and the Maestra in the south-east. The Maestra is the largest mountain range and home to Pico Real del Turquino, the country's highest peak at 1,974 metres.[2]
Climate	The climate is semi-tropical or temperate, except in the mountains. The average minimum temperature is 21 °C and the average maximum is 30 °C. The average relative humidity is 79 per cent. Coas tal areas are relatively cooler due to trade winds and sea breezes. The eastern coast is often hit by hurricanes from June to November.[3,4]
Climate Change	Droughts are common in the region of Eastern Cuba. However, due to climate change effects, the western and central regions have also started to be heavily affected by droughts.[3,4]
Rain Pattern	The rainy season in Cuba lasts from May to October. The average annual precipitation is 1,444 mm, with the mountainous areas on average receiving more than 1,800 mm a year and most of the lowland regions ranging from 900 to 1,400 mm. The area around Guantanamo Bay in the south-east receives less than 650 mm of precipitation a year.[3,4]
Hydrology	The topography and climate of the island result in short rivers with reduced flows. The longest river is the Cauto (249 km long), flowing westwards north of the Maestra. Other major rivers include the Sagua la Grande, the Zaza, the Caonao and the San Pedro. The Toa River (116,2 km), located in the provinces of Holguín and Guantanamo, has the largest volume of flow in the country.[3,4]

ELECTRICITY SECTOR OVERVIEW

In 2019, annual electricity generation in Cuba was approximately 20,700 GWh (Figure 1). Fossil fuel-based thermal power plants contributed approximately 77 per cent, including gas-powered turbines and other thermal power plants from industries (mainly biomass from the sugar cane industry). Grid-connected internal combustion (IC) generators contributed 21 per cent, while hydropower and other renewable energy sources (including wind and solar power) contributed slightly less than 2 per cent combined. Total renewable electricity in 2019 amounted to 894 GWh (4 per cent), including 519 GWh from biomass.[5]

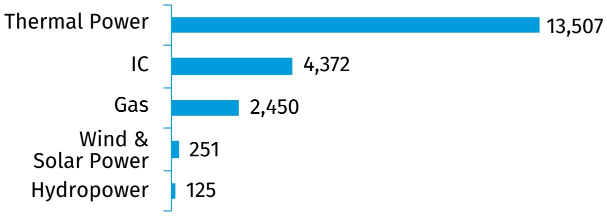
Figure 1. **Annual Electricity Generation by Source in Cuba in 2019 (GWh)**



Source: ONEI[5]

In 2019, installed capacity totalled 6,507.8 MW, with approximately 46 per cent from thermal power plants, including 7 per cent from generators operated by the Ministry of Energy and Mines and the Group of Sugar Industries (AZCUBA). IC power generators contributed 42 per cent, 9 per cent was from gas turbines and 2 per cent from solar photovoltaics (PV) and wind power. Only 1 per cent of installed capacity was from hydropower (Figure 2).[5]

Figure 2. **Installed Electricity Capacity by Source in Cuba in 2019 (MW)**



Source: ONEI[5]

Cuba achieved 100 per cent electrification rate in 2018.[5] Total electricity consumption reached 20,703.2 GWh in 2019, with the residential and public sectors having consumed approximately 45 and 39 per cent, respectively. The gross generation index stood at 1.8 MWh per citizen. Losses amounted to approximately 16 per cent.[5]

The electricity sector in Cuba is fully public, owned by the Electric Union of Cuba (UNE). UNE is part of the Ministry of Energy and Mines (MINEM) and is the main entity responsible for the generation, transmission and distribution of electricity in the country, with the exception of the electricity generated by sugar cane biomass, which is owned by AZCUBA. The National Institute for Hydraulic Resources (INRH) is the regulatory authority responsible for the management of water resources. However, hydropower plants are owned by UNE, via a subsidiary, the Renewable Energy Sources Company (EMFRE). Water use for hydropower generation is subordinated to irrigation and population supply. Furthermore, reservoirs are not built exclusively for electricity production.[5,6,7]

Since 2005, the electricity sector of Cuba has undergone numerous reforms with a new energy development strategy known as the Energy Revolution started in 2006. Notably, the key features of the strategy include the promotion of distributed generation, rehabilitation of electric grids, energy saving and energy education and the promotion of renewable energy sources. The focus of the National Electric System (SEN) has been placed on increasing the use of renewable energy, liquid natural gas and biomass to gradually decrease the share of oil-based thermal power plants.[4,5]

In recent years, the share of combined cycle and IC generators in the country's energy mix has experienced a rise as a result of the efforts to move away from a concentrated system composed of large thermal power plants towards a distributed generation system. The reduced concentration of the country's generation capacity in large thermal power plants has also mitigated the risks posed to the system by hurricane damage. Furthermore, the efforts in achieving a distributed system reduced the consumption of fossil fuels as the energy efficiency of IC generators is higher than that of large thermal power plants.[4] The specific fuel consumption of all power plants in 2018 was 257.7 grams of conventional fuel per kilowatt-hour (g/kWh), however thermal fuel consumption stood at 276.1 g/kWh.[5]

Since January 2021, new electricity tariffs have been introduced for households and the non-residential sector, as part of the country's ongoing process of monetary unification. In particular, electricity tariffs have increased exponentially, with tariffs depending on monthly consumption (Table 1).[8,9] The new average price is approximately three times higher than in the old tariff system, under which 97.8 per cent of the customers consumed up to 500 kWh. The increase of electricity tariffs is directly related to the devaluation of the Cuban Peso, given that the electricity supply of Cuba is heavily dependent on energy imports.[8]

Table 1. **Electricity Tariffs in Cuba in 2021**

Consumption (kWh)	*Price (CUP/kWh (USD/kWh))*	*Consumption (kWh)*	*Price (CUP/kWh (USD/kWh))*
0–100	0.33 (0.01)	501–600	9.20 (0.38)
101–150	1.07 (0.04)	601–700	9.45 (0.39)
151–200	1.43 (0.06)	701–1,000	9.85 (0.41)
201–250	2.46 (0.10)	1,001–1,800	10.80 (0.45)
251–300	3.00 (0.13)	1,801–2,600	11.80 (0.49)
301–350	4.00 (0.17)	2,601–3,400	12.90 (0.54)
351–400	5.00 (0.21)	3,401–4,200	13.95 (0.58)
401–450	6.00 (0.25)	4,201–5,000	15.00 (0.63)
451–500	7.00 (0.29)	>5,000	20.00 (0.84)

Source: MINJUS[9]

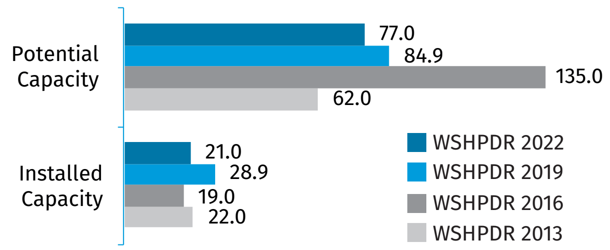
SMALL HYDROPOWER SECTOR OVERVIEW

Cuba has more than one hundred years of experience in the use of hydropower for electricity generation, which was one of the most utilized renewable energy technologies in the first half of the 20th century. Currently, hydropower is the third-largest renewable energy source in Cuba by installed capacity.

There is no official definition of small hydropower (SHP) in Cuba, but unofficially Cuba assumes the terminology of the Latin American Organization of Energy (OLADE) that is less than 5 MW of installed capacity.[10,11] However, for the purposes of this report, a definition of SHP as hydropower plants with an installed capacity of less than 10 MW will be followed.

The current installed operational hydropower capacity in Cuba is 64 MW, with 43 MW from the Hanabanilla hydropower plant and 21 MW from SHP, in accordance with the up to 10 MW definition.[5,12] In comparison with the data from the *World Small Hydropower Development Report (WSHPDR) 2019*, the country's installed SHP capacity has decreased by over 27 per cent while the estimate SHP potential has decreased by 9 per cent, due to access to more accurate data (Figure 3).

Figure 3. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in Cuba (MW)**



Source: *WSHPDR 2019*,[4] ONEI,[5] *WSHPDR 2013*,[13] *WSHPDR 2016*[14]

As of 2020, there were a total of 170 hydropower plants in Cuba. Of these, 138 were operational SHP plants, including 41 SHP plants connected to the SEN and 97 SHP plants (70 per cent) operating in isolation from the SEN, offering service to 8,486 isolated households.[12,15] Currently, 32 SHP plants are identified as non-operational, of which 25 plants lack water supply as a result of climate change and seven are in need of refurbishment.[12] The nine most productive SHP plants in Cuba are listed in Table 2. Given that some SHP plants were commissioned decades ago, they require refurbishment. For budgetary reasons, only the C. M. de Céspedes SHP plant was refurbished in 2019.

Table 2. **List of Most Productive Operational Small Hydropower Plants in Cuba**

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Plant type*	*Operator*	*Launch year*
Mayarí MD	Holguín	2.85	43	Reservoir	UNE	2018
Bueycito	Granma	1.46	30	Reservoir	UNE	2012
Nuevo Mundo	Holguín	2.00	44	Reservoir	UNE	2010
Zaza	Sancti Spíritus	2.70	8	Reservoir	UNE	2009
Corojo	Granma	2.00	33	Reservoir	UNE	2003
Chambas	Ciego de Ávila	1.04	29	Reservoir	UNE	2003
C. M de Céspedes	Santiago de Cuba	1.53	34	Reservoir	UNE	1998
Yara	Granma	2.60	42	Reservoir	UNE	1986
Guaso	Guantanamo	1.05	190	Run-of-river	UNE	1917

Source: Peña Pupo & Fariñas Wong[16]

There are two SHP plants to be completed in 2021: the Alacranes SHPP (2.1 MW) in Villa Clara and the Mayarí MI SHPP (1.25 MW) in Holguín (Table 3). Furthermore, in 2020 a feasibility study of one pumped storage hydropower plant of 200 MW in Mayarí was completed.[6,15] Given that Cuba does not have major rivers or large bodies of inland water, the development of hydropower will remain focused on small-scale projects. The technical potential of hydropower in Cuba is estimated, based on preliminary studies, to be 135 MW, including 13.7 MW in channels.[15] This potential was determined by an inventory of potential sites in the 1980s. The study involved cartographic maps and precipitation measurements, with a few cases where a deep hydrological assessment was carried out. Currently, the estimated capacity of some SHP sites is being increased using hydrological assessment based on field investigations. However, the methods used were developed in Cuba in the 1980s. Thus, the current hydrological design remains weak due to the lack of local expertise in SHP. The updated estimate of SHP potential in Cuba is 77 MW, which is based on previous calculations of 56 MW of total planned capacity and the current installed capacity of 21 MW.[15]

Table 3. **List of Ongoing Small Hydropower Projects**

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Develwoper*	*Planned launch year*	*Development stage*
Alacranes	Villa Clara	2.10	13.0	EMFRE	2021	Construction
Mayarí MI	Holguín	1.25	13.5	EMFRE	2021	Construction

Source: MINEM[15]

SMALL HYDROPOWER PROJECTS AVAILABLE FOR INVESTMENT

In 2016, Cuba signed an agreement with the Kuwait Fund for Arab Economic Development (KFAED), which provided USD 30 million for the construction of 34 SHP projects with a combined capacity of 14.6 MW.[4,17,18] Furthermore, by October 2020, some contracts had been signed with a European supplier (STM Power) for the development of 10 SHP projects and supply of SHP technology. The duration of the project is seven years.[16] Table 4 provides a list of selected sites available for development or refurbishment based on full feasibility studies.

Table 4. **List of Selected Small Hydropower Sites Available for Development and Refurbishment**

Name	*Location*	*Potential capacity (MW)*	*Head (m)*	*Type of site*
Guaso	Guantánamo	1.05	190	Refurbishment
La Paila	Pinar del Río	0.75	19	New
Cautillo	Granma	0.80	21	New
Cauto el Paso 1	Granma	0.65	7	New
Cauto el Paso 2	Granma	0.65	6	New

Source: Peña Pupo & Fariñas Wong[16]

The Government of Cuba drew up plans in 2016 for the development of 74 SHP plants by 2030, representing over 56 MW in capacity (274 GWh), which are available for foreign investment.[19,20] This would nearly double the country's current hydropower capacity, producing an estimated 274 GWh of renewable electricity annually and offsetting up to 230,000 tonnes of CO_2 emissions.[4]

RENEWABLE ENERGY POLICY

The Government of Cuba has recognized the decisive role that renewable energy has to play in the future development of the country. The Government has aspirations to increase the share of renewable energy sources in the country's electricity generation mix to 24 per cent by 2030. This will be composed largely of biomass, wind power and solar PV, with SHP playing a lesser role.[19] The Parliament and the Council of Ministers of Cuba approved the Policy for the Prospective Development of Renewable Energy Sources and the Efficient Use of Energy for 2014–2030 in July 2014.[20] The policy aims to diversify the energy mix by taking into account the use of every renewable energy source. The policy's main objectives are:

- Reducing dependency on fossil fuels and, therefore, increasing energy independence;
- Decreasing the high consumer cost of energy derived from the cost of fuel and the low efficiency of the electricity system;
- Contributing to environmental sustainability;
- Introducing a new foreign investment law.[4,19]

In March 2018, the Government signed Law 345 on the Development of Renewable Sources and the Efficient Use of Energy.[20] The Law also makes provisions for tariff exemptions for the imports of components and equipment for renewable energy projects.[4,20]

The Cuban industry aims to be able to achieve the recovery of production of hydraulic turbines to modernize and upgrade existing SHP facilities. The priorities include the production of new horizontal turbines for micro-hydropower plants as well as the production of speed governors. In addition, the sector looks for foreign investment to strengthen the industry.[15,19] Foreign investments have already contributed to the transition and diversification of the energy mix of Cuba through projects based on solar power, wind power, hydropower, biogas and agricultural as well as industrial residuals such as sugarcane biomass.[19] There are no feed-in tariffs or renewable electricity prices in Cuba, however in the case of foreign investment, the purchase prices and electricity sale can be negotiated.[20]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

The Environmental Law (Law 81-1997) laid the foundation for the recognition of the role of renewable energy in the country's development and has been subsequently added to over the past two decades. In the protected areas, severe environmental regulations are applied, making construction in such areas practically impossible. With regard to hydropower, under Resolution 114-1990, the INRH has the competence to approve the entities (including foreign ones) that are authorized to develop a project related to water.[4,21]

Efficient and responsible management and utilization of water resources have become a national priority since the implementation of the Cuban Programme to Combat Climate Change (Programa Cubano de Enfrentamiento al Cambio Climático) of 2007, the 2012 National Water Policy (Política Nacional del Agua 2012) and Law 124-2017 on terrestrial waters.[7]

The Government of Cuba is open to investment from foreign enterprises in renewable energy projects, by means of either joint ventures with Cuban enterprises or fully-foreign investment.[19] However, Foreign Investment Law (Law 118-2014, replacing Law 77-1995) does not include specific legislation for renewable energy sources, as Law 345 or Decree Law 327 do.[21,22] Law 118 and Decree Law 327 establish the procedures for any type of investment in Cuba. According to Decree Law 327, the investor should make a request to the Institute of Physical Planning, which in its turn will provide an answer within a 60-day period, specifying the technological and environmental regulations that the investor is expected to comply with. Once these requirements are satisfactorily met by the investor a certificate of licences for construction is granted.[20]

FINANCIAL MECHANISM FOR SMALL HYDROPOWER PROJECTS

Cuba is one of the few countries in the world that does not have membership in any major international finance institutions, including the International Monetary Fund (IMF), the World Bank and the Inter-American Development Bank (IDB).[4] However, some loans have been guaranteed by international institutions as well as countries with which Cuba has a longstanding trade tradition and relationship.[15] In January 2018, the Cuba Sustainable Energy Forum was held in Havana, which was attended by participants from the European Union, international energy companies and the private sector. Attracting foreign investment is critical for the Government's goal of achieving USD 3.5 billion of investment into the energy sector. Furthermore, Cuba has been strengthening its engagement with the International Renewable Energy Agency (IRENA) through the SIDS Lighthouses Initiative.[4,23]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Droughts, especially those associated with El Niño episodes, have caused enormous impacts during the past 15 years and are projected to severely affect the Caribbean region in the future. For this reason, specific solutions must be implemented to reduce the risk of a lack of electricity production by SHP plants as foreseen in the National Plan to Confront Climate Change, known as Tarea Vida (Project Life).[24] On the other hand, it is important to stress that half of the country's hydropower potential lies in protected regions with a high biodiversity value, one of the reasons why hydropower has not been developed in Cuba on a larger scale until today.[25]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The SHP sector has a tradition of over one hundred years in Cuba. It is also currently growing despite the existing financial and environmental limitations. There is a well identified potential for the construction of new SHP plants. The existence of a law on foreign investments and of a renewable energy policy constitute an advantage for the further development of SHP in Cuba.

The barriers that have limited the use of SHP in Cuba are similar to those that have limited the development of other renewable energy sources in the country. These technical, social, institutional, economic, financial and regulatory barriers include:

- Lack of advanced technologies to further study hydropower potential;
- Limited financial resources;
- Limited technical capacity to carry out feasibility studies;
- Limited ability of the national industry to ensure the availability of equipment, components and spare parts;
- Low usage of the existing production capacities;
- Limited scientific and technological capacity of the hydropower sector;
- Insufficient maintenance of existing facilities. [26,27]

The main enablers for SHP development in Cuba are as follows:

- Well studied potential hydropower projects available for foreign investment;
- Existence of Government renewable energy plans;
- Existence of legislation and regulations supporting foreign investment.

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Dominica

Davy Rutajoga, International Center on Small Hydro Power (ICSHP)

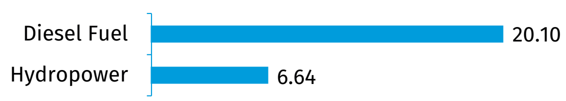
KEY FACTS

Population	71,991 (2020)[1]
Area	751 km²[2]
Topography	Considered the largest and most northerly of the Windward Islands, the country is also part of the rugged Lesser Antilles volcanic arc. An island of volcanic origin, the terrain is very rugged with some active volcanoes and a number of hot springs. Mountains cover both the northern and southern interior, with a small plain in the centre. Its vegetation is lush and green, with dense forests and a tropical flora on steep slopes. The slopes in Dominica vary in elevation from 300 to 1,400 metres above sea level. Its highest peak is Morne Diablotins situated in the northern interior of the island, which reaches 1,447 metres.[2]
Climate	Dominica has a tropical wet climate, characterized by heavy rainfall and warm temperatures. Temperatures rarely fluctuate and the average temperature throughout the year is 27 °C near the coast and in high altitudes it is cooler with an average of 20 °C. During the summer months of July and August days are hot and humid with temperatures typically around 32 °C.[2,3]
Climate Change	An island state in the Caribbean, Dominica is especially vulnerable to a rise in sea level and an increase in natural disasters. Hurricanes are expected to become more prevalent and intense in the upcoming decades, while overall annual rainfall is expected to decrease. Average temperatures have already increased more than 1 °C in the past century along with the number of extremely hot days. These trends are anticipated to accelerate by the end of this century.[3]
Rain Pattern	The weather in Dominica is characterized by strong rains, with rainfall ranging from 1,500 mm at sea level to above 6,000 mm in mountainous areas. The island has both a rainy and a dry season, the former between July and December and the latter from January to June. Hurricanes and tropical storms from the Atlantic Ocean occur during the wet season peaking during late August and September.[2,3]
Hydrology	Dominica contains 365 rivers as well as many waterfalls, which are evenly dissipated across the country. The Layou river is the longest and flows from east to west in the central region. The Roseau, Pagua and Toulaman are the other major rivers and flow from the interior down to the coasts. Most streams are non-navigable but can be used for hydropower generation.[2]

ELECTRICITY SECTOR OVERVIEW

At the end of 2020, total installed capacity in Dominica was 26.74 MW that satisfied a peak demand of 15.96 MW. Of the total installed, diesel fuel accounted for 20.10 MW (75 per cent) and hydropower accounted for 6.64 MW (25 per cent) (Figure 1).[4] Minimal solar and wind power also exists within the country but are self-generated at the residential or commercial level.[5] Accurate data on installed capacity of solar and wind power are currently unavailable. There are a total of five major power plants in the country. The two diesel plants are Fond Cole (13.3 MW) and Sugar Loaf (6.8 MW) and the other three are hydropower plants at Laudat (1.24 MW), Trafalgar (3.52 MW) and Padu (1.88 MW). Available capacity in 2020 was lower than installed due to damages to plants, especially at the Padu hydropower plant that has been damaged since Hurricane Maria in 2017 and still has not been repaired.[4,6]

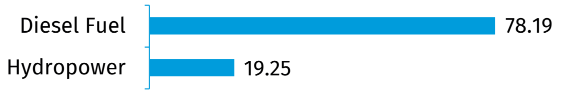
Figure 1. **Installed Electricity Capacity by Source in Dominica in 2020 (MW)**



Source: DOMLEC[4]

In 2020, total electricity generation in Dominica by the country's electricity company, DOMLEC, was 97.45 GWh. Diesel fuel generated 78.19 GWh (approximately 80 per cent) and hydropower 19.25 GWh (20 per cent) (Figure 2). Total electricity sold in the country was 85.5 GWh. Residential customers consumed 40.78 GWh, commercial customers (excluding hotels) consumed 36.41 GWh, industry consumed 3.46 GWh, hotels consumed 2.83 GWh and street lighting consumed 2.03 GWh. Power plants used 3.57 GWh themselves and the remaining 8.37 GWh was considered as losses.[4]

Figure 2. **Annual Electricity Generation by Source in Dominica in 2020 (GWh)**



Source: DOMLEC[4]

Access to electricity in Dominica is 100 per cent.[7] Electricity security in the country, however, is vulnerable to weather volatility and oil price shocks. During the dry season, the hydropower plants are unable to produce at their full capacity.[4] In addition, inclement weather and storms can easily damage the country's electrical infrastructure. Hurricane Maria in 2017 demonstrated how vulnerable the infrastructure was, affecting the entire grid and leaving almost all of the population without power for months. The transmission and distribution system were nearly completely destroyed, with 40 per cent of the system torn down and needing repairs and another 25 per cent was unrepairable and needing to be fully replaced. The irremediable damage was disproportionately higher in rural areas.[5] Since this natural disaster, heavy focus has been put on making the system much more resilient for the future.

The one electrical utility company in the country is Dominica Electricity Services Limited (DOMLEC). The majority of the company is owned by private investors with Light and Power Holdings being its majority shareholder, owning 52.8 per cent. DOMLEC is the country's principal generator of electricity, although independent power producers (IPPs) are allowed to generate electricity with a licence as per the Electricity Supply Act of 2006. Transmission and distribution rights are still exclusive to DOMLEC. The Independent Regulatory Commission (IRC) is responsible for regulating the sector and issuing the generation licences.[6]

Electricity tariffs in Dominica depend on consumer type. For residential consumers prices are 0.11 USD/kWh for the first 50 kWh and 0.13 USD/kWh for additional consumption above 50 kWh. For industries and hotels prices are 0.12 USD/kWh from 6 am to 10 pm and are 0.11 USD/kWh from 10 pm to 6 am. For commercial consumers and street lighting prices are 0.13 USD/kWh.[8] In April 2022 the IRC was to carry out a tariff review of DOMLEC, with tariff values subject to change as a result.[9]

SMALL HYDROPOWER SECTOR OVERVIEW

The definition of small hydropower (SHP) in Dominica refers to plants of up to 10 MW. The installed capacity of SHP was 6.64 MW at the end of 2020. The country has three SHP plants: Laudat with an installed capacity of 1.24 MW, Trafalgar with 3.52 MW and Padu with 1.88 MW.[4] All three plants are owned and operated by DOMLEC. The exact SHP potential in the country is unknown although it has been found that there is untapped potential within the island. A qualitative hydropower potential assessment indicated there was hydropower potential in the Belfast, Layou, Rosalie, Roseau and White Rivers but the undertaken study did not quantify the potential.[10] In comparison with the *World Hydropower Development Report (WSHPDR) 2019*, potential capacity has remained unknown and installed capacity has recovered its 6.64 MW level due to the knowledge that the Padu plant will not be permanently shut down because of the damage caused by Hurricane Maria (Figure 3).

Figure 3. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in Dominica (MW)**

Sources: DOMLEC,[4] *WSHPDR 2019*,[10] *WSHPDR 2016*,[11] *WSHPDR 2013*[12]

Hydropower was first implemented in the country in 1952 with the 0.64 MW Old Trafalgar plant and then in 1967 the 1.88 MW Padu plant was commissioned.[13] Decades later, Dominica expanded its electricity generated through hydropower by implementing the Dominica Hydroelectric Expansion Project, which led to the Laudat power plant commencing its service in December 1990. The Old Trafalgar power plant was replaced by the New Trafalgar in September 1991.[14]

In 2017, Hurricane Maria severely affected the entire country, including its existing hydropower facilities. A study of the Roseau River area found that the Trafalgar hydropower plant only experienced minor damages to the building structure, while the Laudat plant remained intact.[15] Conversely, the Padu hydropower plant was severely affected, with the flooding of its powerhouse and damage to its electrical installations. This has caused the plant to be unable to operate, which remained to be so as of the start of 2022. Plans to recover this plant, however, are in place and international bidding for the rehabilitation project was announced in February 2022.[16]

RENEWABLE ENERGY POLICY

A National Energy Policy (NEP) was drafted in 2011 and revised in 2014, asserting the country's objective for self-sufficient electricity generation through sustainable resources by 2020. It suggested that renewable energy should be included in the energy mix whenever economically feasible. Hydropower, solar power and geothermal power were all listed as having high potentials that should be further studied and developed. Geothermal power was the only one quantified with a capacity target, expecting a capacity of 120 MW to be fully operational by 2020.[17] In reality, high set-up costs have severely hindered reaching this expectation so in order to push geothermal development, the Government created the publicly-owned Dominica Geothermal Development Company Ltd. (DGDC) in 2016, which, at the moment of writing of this chapter, was in the process of constructing a 10 MW geothermal project with USD 50 million invested from the Government.[18] This NEP also suggests enacting financial incentives for renewable energy development; however, no such incentives have been put in place.[17]

In response to the immense damage of the electricity infrastructure caused by Hurricane Maria in 2017 and the need for a more resilient system, the Sustainable and Resilient Energy Plan (S-REP) of 2019 was created. This plan stresses the need to strengthen the country's transmission and distribution systems, to diversify the energy mix with more renewable energy sources and to reinforce grid stability for the most vulnerable communities. Analyses of six scenarios of possible energy mixes were carried out to find the most cost-effective way to maximize resiliency and two scenarios were identified as optimal, depending on actual geothermal output achievements. The most optimal scenario constitutes increasing hydropower capacity to 7.2 MW, geothermal power to 12.8 MW and keeping existing diesel for back-up. However, in the case that geothermal power becomes too expensive to implement at such a capacity, then alternatively increasing solar power to 6.2 MW, wind power to 6.6 MW, geothermal power to 6.4 MW and keeping diesel for back-up, would be satisfactory.[19] All sustainable development programmes and projects in Dominica are coordinated by the Environment Coordinating Unit (ECU) of the Ministry of Environment, Natural Resources, Physical Planning and Fisheries. The ECU is funded primarily by internal sources and collaborates with the Government of the Commonwealth of Dominica and the private sector agencies on developing renewable energy policies as well as tackling environmental issues.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The barriers to SHP development in Dominica include:

- The current focus on electricity generated through geothermal resources has shifted the Government interest away from other renewable energy sources;
- Progress in eco-tourism and the frequent use of rivers for this purpose prevents future hydropower development;
- Dominica lacks economic and financial incentive mechanisms for SHP, such as feed-in-tariffs or tax benefits;
- Privately-owned properties make land-acquisition for hydropower difficult.[10]

The enablers for SHP development in Dominica include:

- Hydropower projects have a lower cost of developing than geothermal projects;
- As SHP plants have been in operation in the country for several decades, there is local operating knowledge;
- An increase in hydropower would decrease the country's high dependency on imported fossil fuels.

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Dominican Republic

Michela Izzo, Guakía Ambiente; Alberto Sánchez, GEF Small Grants Programme; and Mario Vera Barranco, Guakía Ambiente

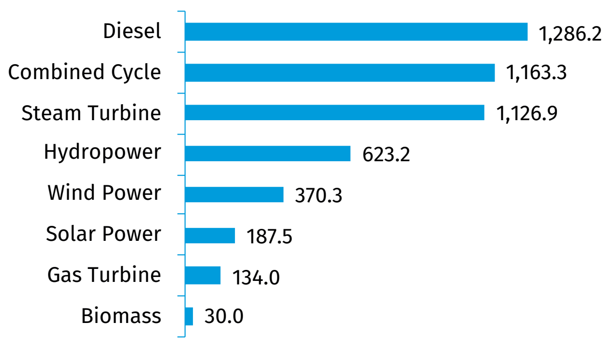
KEY FACTS

Population	10,448,499 (2020) [1]
Area	48,311 km^2 [2]
Topography	The Dominican Republic has four main mountainous chains: the Cordillera Septentrional, the Cordillera Central, the Sierra de Neyba and the Sierra de Bahoruco. These chains run approximately parallel to each other with a north-west, south-east orientation and are separated by three major valleys: the Cibao, the San Juan and the Enriquillo. Pico Duarte is the highest peak in the country, on the island of Hispaniola and in the entire Caribbean, reaching 3,098 metres.[3]
Climate	The Dominican Republic has a tropical climate, ranging from arid to very humid, with high ecosystem diversity. This is associated with the physical geography of the country that is characterized by mountain chains, which create a barrier to trade winds, producing very different conditions between the windward and leeward sides. The average temperature ranges between 7 °C (at the highest altitudes) and 31 °C (at the Enriquillo Lake in the southern region).[3]
Climate Change	Historical trends show a significant increase in air temperature (3.0±0.5 °C for minimum and 1.8±0.4 °C for maximum air temperature in the period 1936–2007) and significant change in rain patterns, with typical reduction in precipitation on the leeward side of the main mountain chains and the western side of the country.[4] These trends are expected to continue and intensify in the future, according to the most accredited climate change scenarios.[5]
Rain Pattern	Variations in topography lead to differences in precipitation of up to 2,400 mm between the north-eastern and south-western sides of the Cordillera Central. The wettest areas are located in the north-eastern part of the country, which receive annual rainfalls of over 3,000 mm, while the driest areas can be found in the Enriquillo Valley, in the south-west, with less than 450 mm of precipitation per year.[3]
Hydrology	The Yaque del Norte (296 km) is the longest river in the Dominican Republic. The longest river on the island of Hispaniola is the Artibonite (321 km); however, only 68 km of it are located in the Dominican Republic. On the other hand, the largest river of the country is the Yuna, with an average flow of 97.6 m^3/s.[6] Lake Enriquillo is the largest lake not only in the Dominican Republic, but also in the entire West Indies.[3]

ELECTRICITY SECTOR OVERVIEW

In 2020, total installed capacity in the Dominican Republic stood at 4,921.4 MW, representing an increase of approximately 42 per cent compared with 2016. Of the total installed capacity, approximately 26 per cent came from diesel plants, 24 per cent from combined cycle plants, 24 per cent from steam turbine plants and 3 per cent from gas turbine plants (Figure 1). Renewable energy sources contributed approximately 24 per cent of the total, with hydropower, the country's most important energy source after fossil fuels, providing 13 per cent and wind power plants 8 per cent. Biomass was recently added to the country's energy mix, with a 30 MW plant installed in the south-east of the country.[7,8,9]

Figure 1. **Installed Electricity Capacity by source in the Dominican Republic in 2020 (MW)**



Source: OCSENI,[7] Sanchez & Izzo[9]

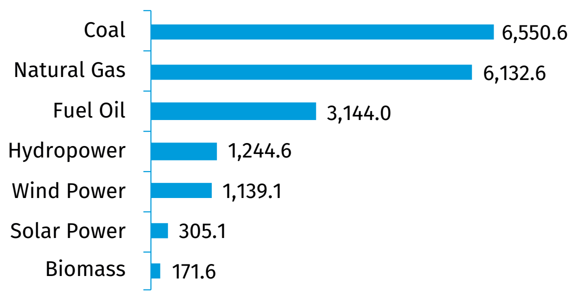
Total gross generation in 2020 reached 18,687.6 GWh, while net supplied electricity was 17,411.5 GWh. Of total electricity generation, coal contributed 35 per cent (with a significant increase from previous years due to the launch of the Punta Catalina power plant), natural gas 33 per cent, fuel oil 17 per cent, hydropower 7 per cent, wind power 6 per cent, solar power 2 per cent and biomass 1 per cent (Figure 2). Relative to the *World Small Hydropower Development Report (WSHPDR) 2019*, there was a significant increase in both generation from fossil fuels (especially carbon and diesel) and generation from renewable energy sources, especially solar and wind power, while generation from hydropower remained basically stable.[7,8,9]

Table 1. **List of Operational Small Hydropower Plants in the Dominican Republic**

Name	*Location*	*Capacity (MW)*	*Head*	*Plant type*	*Operator*	*Launch year*
Brazo Derecho	Santiago province, UFE Canal	2.9	24.5	Kaplan	EGEHID	2011
Las Barías	Peravia province, Marcos A. Cabral Canal	0.9	9.9	Kaplan	EGEHID	2010
Magueyal 1	Azua province, Ysura Canal	1.5	60.0	Francis	EGEHID	2009
Magueyal 2	Azua province, Ysura Canal	1.5	60.0	Francis	EGEHID	2009
Rosa Julia de la Cruz	María Trinidad Sánchez province, Boba River	0.9	10.5	Kaplan	EGEHID	2005
Domingo Rodríguez 1	San Juan province, José Joaquón Puello Canal	2.0	54.4	Francis	EGEHID	2004
Domingo Rodríguez 2	San Juan province, José Joaquón Puello Canal	2.0	54.4	Francis	EGEHID	2004
Aniana Vargas 1	Monseñor Nouel province, Yuboa River	0.3	40.0	Francis	EGEHID	2003
Aniana Vargas 2	Monseñor Nouel province, Yuboa River	0.3	40.0	Francis	EGEHID	2003
Los Toros 1	Azua province, Ysura Canal	4.9	N/A	Francis	EGEHID	2001
Los Toros 2	Azua province, Ysura Canal	4.9	N/A	Francis	EGEHID	2001
Los Anones	Peravia province, Marcos A. Cabral Canal	0.1	7.0	Francis	EGEHID	1999
Contra embalse Monción 1	Santiago Rodríguez province, Mao River	1.6	15.5	Francis	EGEHID	1998
Contra embalse Monción 2	Santiago Rodríguez province, Mao River	1.6	15.5	Francis	EGEHID	1998
El Salto	La Vega province, Constanza River	0.7	77.0	Ossberger	EGEHID	1995
Baiguaque 1	Santiago province, Baiguaque River	0.6	78.0	Ossberger	EGEHID	1995
Baiguaque 2	Santiago province, Baiguaque River	0.6	78.0	Ossberger	EGEHID	1995
Nizao Najayo	San Cristóbal province, Nizao-Najayo Canal	0.3	10.0	Ossberger	EGEHID	1994
Hatillo	Juan Sánchez Ramírez province, Yuna River	8.0	30.0	Francis	EGEHID	1984
Sabaneta	Azua province, San Juan River	6.3	70.0	Francis	EGEHID	1981
Las Damas	Independencia province, Las Damas River	7.5	304.0	Pelton	EGEHID	1967
Jimenoa	La Vega province, Jimenoa River	8.4	212.7	Francis	EGEHID	1950
Community micro hydropower systems (56)	Various upland basins	1.5	37-150	Mainly Pelton, but also Francis, Turgo, and Mitchell-Banki	Beneficiary communities	1998

Source: INDRHI,[22] Rodríguez Taveras,[23] CESEL Ingenieros[24]

Figure 2. **Electricity Generation by Source in Dominican Republic in 2020 (GWh)**

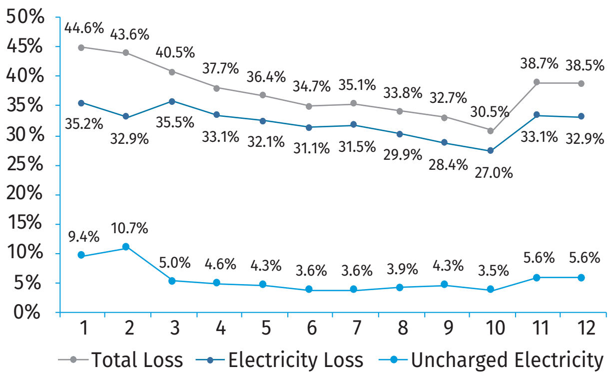


Source: OCSENI,[7] Sanchez & Izzo[9]

The national electricity system of the Dominican Republic has progressively improved in quality. Nevertheless, problems persist, both in terms of energy provision and in terms of quality of transmission and distribution. In order to limit losses and reduce the electricity subsidy, the distribution enterprises (EDEs) have established maximum unit costs for dispatch to the National Interconnected Electric System (SENI), consequently causing an unsatisfied demand. In 2020, the monthly average power demand supply shortfall was 60 MW.[7] Furthermore, the electricity system is characterized by frequent interruptions and a high loss rate both in the transmission and distribution system — over 30 per cent of the total generated electricity (Figure 3).[10] The Dominican Republic experiences one of the highest frequencies of blackouts among countries in the region, exceeding 30 days annually on average.[11] Available capacity stands on average at approximately 22 per cent of installed capacity.[12]

The inability to provide a reliable service at reasonable prices has caused a segmentation of the electrical market into three main groups: SENI's users, who are connected to the national grid and constitute 83 per cent of the market at present; self-producers (10 per cent of the market), typically large consumers such as industrial and mining companies that have their own generation systems to satisfy their internal demand and sell the surplus to SENI; and isolated systems (7 per cent of the market), which operate independently and are not connected to SENI.[13]

Figure 3. **Electricity Loss Rate of Distribution Enterprises as a Percentage of Electricity Charged in the Dominican Republic in 2009–2020 (%)**

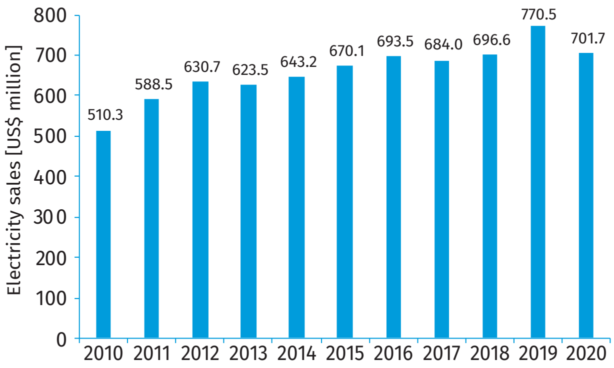


Source: CREES[10]

In terms of access to electricity, the Dominican Republic has made progress in recent years, reaching 100 per cent of urban electrification, while in rural areas electricity access is estimated at 98 per cent.[14,15]

Fossil fuels, which are imported, continue to be the main source of fuel for electrical generation. Given the rising trend in electricity demand, the rate of fossil fuel consumption related to electrical generation is also growing. The expenditure of the residential and commercial sectors on electricity has increased by more than 40 per cent between 2009 and 2019 (Figure 4).[7,16] National projections indicate that energy demand will continue to grow at an average rate of 2–3 per cent per year in the period 2010–2030.[17]

Figure 4. **Electricity Sales to Regular Commercial and Residential Customers in the Dominican Republic in 2009–2019 (USD million)**



Source: CDEEE[16]

The Dominican electrical system is state-owned. However, both the Government and the private sector participate in the generation, transmission, distribution and commercialization of energy. The Coordinator of the National Interconnected System (OCSENI) is the state agency responsible for coordinating the transmission, generation and distribution within SENI. Through Law 141–97, five enterprises were created, two for thermal generation (Electricity Generation Enterprises ITABO and HAINA — EGEITABO and EGEHAINA, respectively) and three for distribution (Electricity Distribution Enterprises of the North, South and East — EDENORTE, EDESUR and EDEESTE, respectively). Both transmission and hydropower generation belong to the state, through two enterprises: one for transmission (Dominican State Transmission Enterprise — ETED) and one for hydropower (Dominican Hydropower Generation Enterprise — EGEHID). The Dominican Corporation of State Electrical Enterprises (CDEEE) is responsible for the management of electrical enterprises and the implementation of state programmes for rural and urban electrification, guaranteeing synergy, effectiveness, profitability and sustainability.[8]

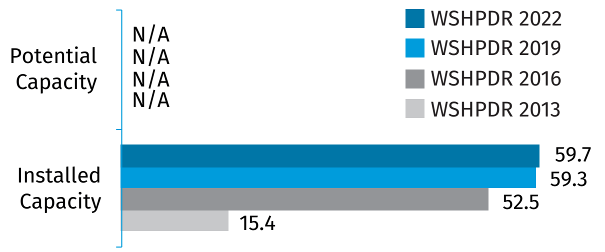
The Dominican Republic continues to have one of the most expensive electrical systems in the Caribbean and Central America. In 2019, final customers had to pay more than 0.15 USD/kWh, over two times the 0.06 USD/kWh paid by customers connected to the off-grid community-owned hydropower plants supported by the Small Grants Programme and the Government of the Dominican Republic, as outlined below.[9,16,18]

There are two different types of electricity subsidies in the Dominican Republic. The first type is the "Bonoluz, 3 in 1", which is a full subsidy of electricity consumption up to 100 kWh for customers who have been selected by the Social Cabinet of the Government. For additional consumption, a further subsidy is provided in the form of a lower tariff, and the fixed charge for consumption is also fully subsidized. The second type of subsidy is the Fund for the Stabilization of the Electric Tariff (FETE) which compensates tariff differences caused by the fluctuations in the cost of imported fuels used for power generation.[8]

SMALL HYDROPOWER SECTOR OVERVIEW

In the Dominican Republic, small hydropower (SHP) is classified as plants with a total capacity of up to 10 MW. Installed SHP capacity in 2020 stood at approximately 59.7 MW, with a total of 76 operational SHP plants, which contributed nearly 10 per cent of the total hydropower installed capacity.[9,19] Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity slightly increased due to the construction of additional community-operated SHP plants, while the nationwide potential remains unknown (Figure 5).

Figure 5. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in the Dominican Republic (MW)**



Source: Sánchez & Izzo,[9] *WSHPDR* 2019,[8] EGEHYD,[19] *WSHPDR 2013*,[20] *WSHPDR 2016*[21]

In 2020, there were 16 state-owned SHP plants consisting of 22 individual power blocks operating in the country with a combined installed capacity of 57.8 MW, all operated by EGEHID.[7] More than 60 per cent of the plants have a capacity of less than 2.5 MW. The majority of these SHP plants, accounting for 80 per cent of the total SHP installed capacity, are located in the Cordillera Central, the main mountain chain of the country. The real capacity of the state-owned SHP plants available to the national electricity system of the Dominican Republic is approximately 45 per cent of their installed capacity on average. In addition, as of 2020 there were 56 community-owned micro-hydropower plants operating in the country, of which 47 were constructed through a partnership between the Government of the Dominican Republic and the Global Environment Facility Small Grants Programme (GEF SGP) and a further 9 were financed solely by the Government. The capacities of these micro-hydropower plants range from 10 kW to 150 kW, with a combined installed capacity of 1.5 MW (Table 1).[7,30]

A comprehensive study on SHP potential in the Dominican Republic has not yet been carried out. One study, which was due to start in 2018 as a collaboration among the Ministry of Energy and Mines, the GEF SGP, the Technological Institute of Santo Domingo (INTEC) and the Dominican non-governmental organization Guakía Ambiente, was delayed. Nevertheless, a pilot study to evaluate micro-hydropower potential was carried out as part of an MSc thesis in 2020, as a collaboration between the University of Madrid, Guakía Ambiente and the GEF SGP. The pilot study was implemented in the Nizao basin, a 1,038 km^2 watershed in the south-eastern region and one of the priority basins of the country, both in terms of water provision and of electricity generation.[25] The study identified 72 river sections appropriate for the installation of micro-hydropower plants: 27 sections between 19 kW and 40 kW, 19 between 40 kW and 70 kW, 13 between 70 kW and 148 kW, 4 between 148 kW and 244 kW, 5 between 244 kW and 372 kW and 4 of more than 372 kW.[26] While these partial results cannot be adopted as an estimate of the nationwide SHP potential, the results and their potential applications confirm the importance of expanding the pilot study to the whole country.

The aforementioned study is especially relevant to organizing rural electrification in a more efficient and effective way, due to the significance that community micro-hydropower generation has acquired in the Dominican Republic as a successful model for sustainable development. The Dominican Government, following Law 57-07 on Incentives to Renewable Energy and in collaboration with multiple stakeholders, continues to promote micro-hydropower as a solution to guarantee electricity access to rural communities while fostering local empowerment. As of 2021, 60 community-owned micro-hydropower plants were in operation, providing clean reliable energy to more than 4,600 families, schools, rural health and community centres, micro-enterprises and communication centres in rural isolated areas. Furthermore, these systems are contributing to global warming mitigation, with a reduction of more than 28,000 tons of CO_2 per year and conservation of over 70 km^2 of forest.[9,27,28,29]

Ten additional SHP plants are currently under construction, with a total capacity of more than 490 kW, which will benefit over 1,100 additional families in isolated rural areas.[27] Several ongoing projects are listed in Table 2, while one potential identified SHP site is listed in Table 3.

Table 2. **List of Selected Ongoing Small Hydropower Projects in the Dominican Republic**

Name	*Location*	*Capacity (kW)*	*Head*	*Developer*	*Planned launch year*	*Development stage*
Los Montazos	La Vega province	50	49	SGP/ Guakía Ambiente	2021	75%
La Yuca – Florencio	San José de Ocoa province	44	80	SGP/ Guakía Ambiente	2022	50%
Los Martínez	San José de Ocoa province	50	135	SGP/ Guakía Ambiente	2022	50%
La Malanga	Barahona province	20	82	SGP/ Guakía Ambiente	2022	40%
Angostura	La Vega province	75	57	SGP/ Guakía Ambiente	2023	35%

Source: SGP/Guakía Ambiente[30]

Table 3. **Potential Small Hydropower Site in the Dominican Republic**

Name	*Location*	*Potential capacity (kW)*	*Head*	*Type of site (New/ Refurbishment)*
Sonador	Monseñor Nouel province	100	50	New

Source: SGP/Guakía Ambiente[30]

Due to the COVID-19 pandemic, community micro-hydropower projects in the Dominican Republic have suffered delays and difficulties, which have slowed the increase in the number of such plants throughout the country.

The Dominican Republic is sharing its successful experience in community micro-hydropower with other Latin American countries (Venezuela, Haiti and Mexico), promoting the application of principles that ensure a sustainable model of micro-hydropower development:

- Community-based approach;
- Development of local solutions;
- Replicability, through adaptation to each specific context;
- Local empowerment, based on the following: respect for the habits and peculiarities of local populations; active participation of people and local groups; learning by doing; improvement of local skills and knowledge; integrated development; and networking and multi-stakeholder synergy. [31]

RENEWABLE ENERGY POLICY

One of the instruments of national policy on renewable energy in the Dominican Republic is the Incentive to the Development of Renewable Energy Sources (Law 57-07) and the corresponding regulations (in particular, No. 10469 of 30 May 2008). The law introduced a target of 20 per cent of national energy consumption to be produced from renewable energy sources by 2020, with the aim of reducing the dependence on imported oil and other liquid fuels. This goal is confirmed by the National Strategy of Development 2030 (Law 01-12), which set the goal of reducing per capita CO_2 emissions by 25 per cent by 2030 with respect to the 2010 baseline.[32] The Government will continue promoting renewable energy over the coming decade, planning to generate 23 per cent of all electricity at the national level from renewable energy sources by 2030. These goals will be reached through structural interventions to improve the national electricity system, as well as changes to the national energy mix.[10]

The regulations for the application of Law 57-07 establish incentives and feed-in tariffs (FITs) for renewable energy, according to the specific source. However, these do not apply to hydropower, small or otherwise. For other RES, FITs range from 0.0487-0.5350 USD/kWh.[29]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

SHP projects are primarily regulated by the General Law on Electricity (125-01), which created the Dominican Hydropower Generation Enterprise (EGEHID), the entity that is responsible for managing all hydropower owned by the Government of the Dominican Republic.[33] SHP projects up to 5 MW can apply for incentives under Law 57-07. In these cases, the state grants concessions to private companies or individuals.

COST OF SMALL HYDROPOWER DEVELOPMENT

Cost of SHP development is highly variable, depending on site conditions, accessibility, technology and grid distribution (where applicable). At present, no case studies are available on the matter. According to the experience of the GEF SGP, the cost of SHP development in the Dominican Republic falls within the range of 6,500–19,500 USD/kW.[34]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

A variety of financial mechanisms are implemented for project development. In case of the Government-developed projects, most have been financed by loans from international banks and less frequently through local funds by selling energy through EGEHID. In case of community SHP projects, financial mechanisms are based on different sources, including international cooperation, the national Government, the private sector, civil society organizations and local communities. During the past 20 years, the GEF SGP has been the main promoter of SHP, with the implementation of more than 50 projects.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Climate crisis is significantly affecting SHP development in the Dominican Republic. On the one hand, the increase in frequency of intense rain, as well as in intensity of tropical cyclones, exposes SHP infrastructure to damage, causing suspension of operations.[4,35] On the other hand, prolonged and intense droughts significantly reduce water flow, thus causing shortages in the provision of electricity.[32] A recent study, carried out on SHP projects supported by the GEF SGP and Guakía Ambiente, revealed that during the period 2015–2018, characterized by the incidence of El Niño, approximately 30 per cent of the plants reduced their generation, while another 15 per cent went out of operation for at least one month.[36]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

SHP generation continues to be a feasible alternative to fossil fuels for electrification in the Dominican Republic, especially in rural isolated areas, where a small percentage of the population persists without access to electricity. Decentralized management is highly recommended to ensure sustainability and to promote local development, especially in case of SHP plants with an installed capacity up to 500 kW.

Many barriers to effective SHP development in the country persist and additional challenges have arisen in recent years, including the following:

- Climate change impacts including intense rain, tropical cyclones, and prolonged drought;
- Insufficient data on undeveloped SHP capacity and potential sites, particularly on the national level;
- Lack of private sector engagement in SHP development;
- Lack of opportunities and mechanisms for knowledge exchange in the SHP sector;
- Lengthy administrative procedures, especially for community-run SHP projects.

Enablers for SHP development include:

- Experience with SHP development and operation and well-organized SHP sector;
- Availability of international financing for SHP projects;
- Some studies of potential SHP sites are available.

Recommended measures in support of SHP development in the Dominican Republic include the following:

- Carrying out a study on SHP potential at the national level;
- Decentralization in decision making;
- Diffusion of a shared vision of integral development, based on local empowerment as a key assumption for sustainability;
- Capacity building for fund management at community level;
- Strengthening of public-private-community alliances, through effective mechanisms of collaboration towards common objectives;
- Opening of opportunities for feeding directly into the grid for SHP plants up to 5 MW;
- Effective application of Law 57-07, especially regarding the commitment to devote 5 per cent from taxes on fossil fuels to renewable energy;
- Providing access to Bonoluz subsidy for households connected to micro-hydropower plants;
- Easy access to the carbon market for community micro-hydropower projects;
- Networking to facilitate knowledge exchange and promote mutual support, while focusing on tackling existing issues in the energy sector;
- Climate change adaptation and land degradation reduction in the main watersheds of the country;
- Ensuring reliable data availability and access.

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Grenada

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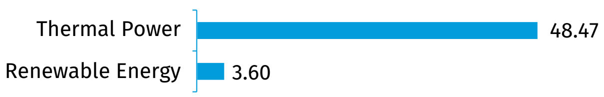
KEY FACTS

Population	112,519 (2020)[1]
Area	345 km^2 (incl. the islands of Grenada, Carriacou and Petite Martinique)[2]
Topography	The oval-shaped main island of Grenada has a rugged terrain of volcanic origin. It features several forested steep slopes rising from sea level. The highest point is Mount Saint Catherine at 840 metres, situated towards the northern interior of the island.[2]
Climate	Grenada has a tropical climate, with an average temperature of 28 °C. Daytime temperatures vary between 26 °C and 32 °C, while at night temperatures can drop to between 19 °C and 24 °C. There is little variation in temperature throughout the year and seasons are categorized by precipitation with the dry season being between January and May and the wet season between June and December.[3]
Climate Change	An increase in major natural disasters is the most critical concern for Grenada on the issue of climate change. Hurricanes are expected to become larger and more frequent in the upcoming decades. In addition, a rise in sea levels could cause devastating damage to the country as most of the population and infrastructure is located along the low-lying coasts. Sea levels have started to rise on the shores at an average rate of 3.6 mm per year since 1993. Some rivers, already prone to flooding, will also most likely experience more dramatic floods in the future.[4]
Rain Pattern	Rainfall varies between altitudes and seasons. Average precipitation on the coasts is 1,500 mm per year and can reach approximately 4,000 mm per year in the interior highlands. The most rainfall is experienced between June and December. It is during these months that tropical storms or hurricanes can occur.[2]
Hydrology	The country has over 70 rivers, mostly small, typically flowing downwards from the higher altitudes in the interior. Of these, there are eight rivers of consequence: Grand River, Beausejour, Pearls, Saint Patricks, Bailes Bacolet, Antoine, Saint Johns and Saint Marks. The rivers are subject to flooding during the wet season, particularly in the upper parts in higher elevations. The largest lake is Grand Etang with a surface area of 8 hectares, located in a dormant volcanic crater.[3]

ELECTRICITY SECTOR OVERVIEW

At the end of 2020, the total installed capacity in Grenada was 52.07 MW that satisfied a peak demand of approximately 32 MW. Over 93 per cent, more than 48 MW, of the capacity was thermal power, primarily diesel fuel. The remaining 7 per cent, or almost 4 MW, was from renewable energy sources, primarily solar power and minimal wind power (Figure 1). The majority of the renewable energy (2.4 MW) was generated through solar photovoltaics (PV) panels of private customers whose excess after personal use is fed back into the grid.[5]

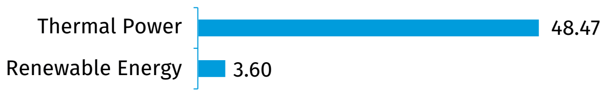
Figure 1. **Installed Electricity Capacity by Source in Grenada in 2020 (MW)**



Source: GRENLEC[5]

Total electricity generation in Grenada for the year of 2020 was 222.7 GWh. Thermal power generated 218.5 GWh, or 98 per cent, and the remaining 4.2 GWh, or 2 per cent, was generated with renewable energy (Figure 2). Subtracting the energy used to operate the power plants themselves, total net electricity generation was almost 213 GWh. Of this, just under 105 GWh (49 per cent) was consumed by the commercial sector, 84 GWh (39 per cent) was consumed by the residential sector and 11 GWh (5 per cent) was used for street lighting. The country experienced an approximately 7 per cent loss in electricity for the year.[5] The electrification rate in Grenada was over 95 per cent as of 2020.[6]

Figure 2. **Annual Electricity Generation by Source in Grenada in 2020 (GWh)**



Source: GRENLEC[5]

Grenada Electricity Services Limited (GRENLEC) is the only electricity company in the country and is therefore responsible for all the generation, transmission and distribution of electricity. GRENLEC was a state-owned company prior to 1994 when it was privatized due to the passing of the Electricity Supply Act that year. The act guaranteed GRENLEC as the sole producer of electricity in the country, but allowed ownership of the company to be transferred to private entities. Consequently, controlling shares were sold to WRB Enterprise from the United States.[7]

The sector was then restructured with the passing of the new Electricity Supply Act of 2016 and the Public Utilities Regulatory Commission Act of 2016. These acts ended GRENLEC's monopoly in the sector, allowing for new entities, domestic or foreign, to begin generating electricity including self-generation for individuals and created a regulatory commission to oversee tariffs in the sector.[7,8] The Electricity Supply Act also called for the promotion of renewable energy and obligates preference given to generators of renewable energy for licences.[9] In the years following the acts, GRENLEC remains the principal supplier of electricity, although its ownership has changed. As of December of 2020, the Government of Grenada repurchased over 71 per cent of the company's shares from WRB Enterprises, making the state the majority owner again.[5]

The base rates of electricity in Grenada depend on the type of consumer in which some types also carry a surcharge for horsepower, floor area or an environmental levy. A value-added tax (VAT) is then added to the final cost for all consumers. Fuel surcharges are calculated based on a three-month average. In March 2022, the base fuel charge for all types of consumers was XCD 0.5288 (USD 0.20) per kWh. The non-fuel charge is different for each type of consumer: for domestic customers it is XCD 0.3043 (USD 0.11) per kWh, for commercial customers it is XCD 0.3281 (USD 0.12) per kWh, for industrial customers it is XCD 0.2405 (USD 0.089) per kWh and for street lighting it is XCD 0.2875 (USD 0.11) per kWh.[10]

SMALL HYDROPOWER SECTOR OVERVIEW

As there is no local definition for small hydropower (SHP). In this chapter it is defined as plants with a capacity of up to 10 MW. While potential SHP capacity in Grenada is estimated to be approximately 7 MW, there is currently no installed capacity. This information remains the same compared to the previous editions of the *World Small Hydropower Development Reports (WSHPDR)* (Figure 3).

In the past, sugar cane estates used hydro wheels to operate mills, but none of these early hydropower plants are in operation today. Several studies have been undertaken to assess the hydropower potential in the country. An analysis carried out in 1981 by the French firm SCET concluded that Grenada has a cumulative potential of at least 7 MW. In 1984, six potential hydropower projects were analysed in a pre-feasibility study at the Great, Marquis and St. Mark's Rivers. In 1991, the British consulting firm MRM Partnership confirmed the hydropower potential of the Great River Upper Basin, including a 720 kW Birchgrove and a 380 kW Belvidere hydropower projects.[11] In 2018, a grant of approximately USD 100,000, most of which financed by the Global Environment Facility (GEF), was approved for a 30 kW hydropower project in Birchgrove, however completion of the construction has not been announced as of yet.[14] Additionally, in 2022, the German Development Corporation (GIZ) was partnering with the Government of Grenada and its water authority, the National Water and Sewage Authority (NAWASA), to bring the possibility of pumps-as-turbines technology to the island, which, if implemented, will generate hydropower in existing water pipes that currently bring potable water from the mountains down to the coasts.[15]

Figure 3. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in Grenada (in MW)**

Source: *WSHPDR 2019*,[11] *WSHPDR 2016*,[12] *WSHPDR 2013*[13]

SHP development in Grenada has not been explicitly prioritized by the Government further than the general goal to expand renewable energy declared in the Energy Supply Act of 2016. The National Energy Policy of 2011 specifically discusses solar power, wind power and geothermal energy but does not mention hydropower.[16] Nevertheless, any SHP generation development would be granted grid preference under the Energy Supply Act and would be regulated as per the Public Utilities Regulatory Commission Act. Financing for these projects would most likely come from international donors, such as foreign organizations or development banks.[11]

RENEWABLE ENERGY POLICY

The National Energy Policy of 2011 states the importance of transitioning to renewable energy and set the goal to generate 20 per cent of the country's energy from renewable sources by 2020.[16] This goal was made with the idea that geothermal energy would be in operation by then, however, it has still not yet been developed and therefore the goal was not reached. Additionally, in the country's first Nationally Determined Contribution of 2016, a target was set to reach an installed capacity of 15 MW of geothermal energy, 10 MW of solar energy and 2 MW of wind energy by 2025, but the second Nationally Determined Contribution of 2020 recognized that this target will most likely not be met.[17,18]

The national power company, GRENLEC, offers a Renewable Energy Interconnection Programme that allows private owners of solar PV systems to sell the extra energy produced back into the grid. This is a net-billing system where customers receive credit for the value of the amount of fuel that was avoided due to the solar power supplied.[19] Owners of the renewable energy-based generators selling electricity to GRENLEC are remunerated either at a fixed rate of XCD 0.45 (USD 0.17) per kWh or at a variable rate equal to the average fuel price per kWh of the previous year, which for 2022 was XCD 0.37 (USD 0.14) per kWh.[10] As of 2020, over 2.4 MW was connected to the grid from customers in this programme.[5]

BARRIERS AND ENABLERS FOR SMALL HYDRPOWER DEVELOPMENT

The key barriers to SHP development in Grenada include:

- The national focus being on geothermal and solar power resources, with a secondary focus on wind power, while hydropower does not play any role in the country's energy supply planning;
- No incentives or other special framework conditions for hydropower development have been created;
- The country's hydropower potential is poorly investigated;
- The lack of local expertise in hydropower.

The key enabler to SHP development in Grenada is as follows:

- With high dependency on diesel fuel and unmet goals to reach a level of 20 per cent of energy sourced from renewable energy, hydropower can be used to help reach the country's goal.

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Guadeloupe

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KEY FACTS

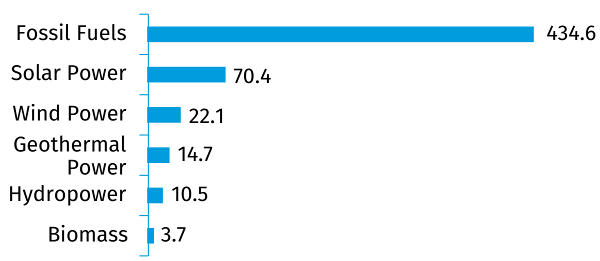
Population	400,020 (2021) [1]
Area	1,690 km² [1]
Topography	Composed of the two main islands of Basse-Terre and Grande-Terre, Guadeloupe is an archipelago that also includes multiple smaller islands. The two main islands are joined together only by a few bridges on a narrow sea channel and a mangrove swamp. Guadeloupe is characterized by a volcanic relief, with its highest point measuring 1,467 metres on the Soufriere Volcano.[2]
Climate	The climate is tropical, characterized by humidity and high temperatures all year round. A remarkable stability is observed in monthly temperatures, which may be attributed to *Les Alizés*, the trade winds. There are two main and distinct seasons in Guadeloupe: the rainy season lasting between June and November and the dry season commencing in December and ending in May. Average temperatures in inland and coastal areas differ by only a few degrees Celsius. In inland areas, temperatures are between 19 °C and 27 °C, while on the coast temperatures reach 22–30 °C. The region is affected by hurricanes that most frequently occur in September, but also anytime during the rainy season, between June and November.[3]
Climate Change	With climate change and the progressive sea level rise, the archipelago is highly exposed to coastal risks, particularly given the increasing concentration of population and economic activities along the coast.[4] Climate change is predicted to lead to the deterioration of coastal areas, erosion of beaches and coral beds, increasing likelihood of flooding and water stagnation in coastal plains, which will eventually damage the soil resistance and coastal infrastructures such as sanitation, drinking water, electricity and roads. Average temperatures are expected to increase by 1.6–4.3 °C by 2010 and heavy rains are expected to become 5–10 times more frequent.[5]
Rain Pattern	The average annual precipitation is 1,814 mm. Rainstorms pass very quickly in general and rain showers are likely to occur at any time during the year, not only between June and November. September is considered the wettest month, while February is historically the driest.[6]
Hydrology	The Guadeloupe National Park on the island of Basse-Terre, where most rivers are located, is the main source of water in Guadeloupe.[5] Some of the most important rivers in Basse-Terre are the Lézarde, Moustique, Rose and Petite Rivière à Goyaves. Canal Perrin and Rivière des Coudes are located on Grande-Terre. Grande-Terre and Basse-Terre are separated by the Salt River. Small islands and the dry regions of Grande-Terre are supplied with water through the developed storage capacities and tapped resources.[7,8]

ELECTRICITY SECTOR OVERVIEW

In 2020, the total electricity generation in Guadeloupe was 1,689 GWh.[9] Most of the electricity was generated from fossil fuels such as diesel and coal. Only approximately 23 per cent was from renewable energy sources (Figure 1).

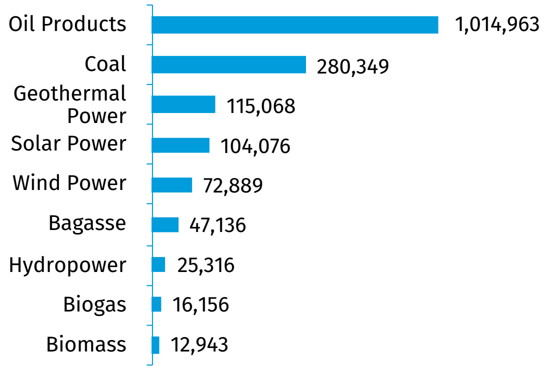
The total installed electricity capacity in Guadeloupe was 556 MW in 2018, with 435 MW from fossil fuel-fired plants and 121 MW from renewable energy sources (Figure 2).[10] Guadeloupe is, thus, highly dependent on fossil fuel generation (coal, diesel and combustion turbines), which account for 80 per cent of the electricity consumed in the archipelago.[11]

Figure 1. **Annual Electricity Generation by Source in Guadeloupe in 2020 (MWh)**



Source: DEAL[9]

Figure 2. **Installed Electricity Capacity by Source in Guadeloupe in 2018 (MW)**



Source: NREL[10]

The Guadeloupe Archipelago is a non-interconnected zone and generates all of its electricity. The islands are connected via submarine cables linked to the network of overhead lines covering Basse-Terre and Grande-Terre.[11]

The Electricity of France (EDF) is the transmission and distribution utility on the archipelago and also operates a significant portion of the country's fossil energy generation. There are also some independent power producers (IPPs), which primarily produce renewable electricity. The Commission for Regulation of Energy (CRE) regulates the electricity sector in Guadeloupe.[12]

Electricity tariff rates in Guadeloupe are defined by the French electricity regulations and are approximately USD 0.19 per kWh.[10,13]

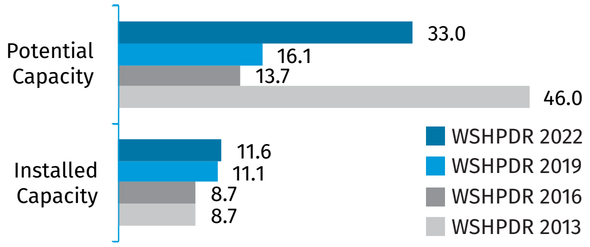
SMALL HYDROPOWER SECTOR OVERVIEW

Small hydropower (SHP) is defined in Guadeloupe as hydropower plants with capacity up to 10 MW. According to the Department of Environment, Planning and Housing (DEAL), Guadeloupe has 16 SHP plants with a total installed capacity of 11.59 MW (Table 1).[14] The existing plants are mainly located in Basse-Terre, due to the combination of available water conditions and suitable topography. These plants are primarily integrated into four irrigation networks and are spread over the Capesterre Belle Eau, Baillif and Vieux-Habitants Rivers. The only plants on Grande-Terre are the Letaye and Gaschet SHP plants.[15]

In 2019 and 2020 SHP plants produced 44 GWh and 25 GWh of electricity, respectively, representing approximately between 2 per cent and 3 per cent of the electricity consumed in the country.[14] The drastic decrease in SHP generation between 2019 and 2020 was due to a 30–40 per cent lower than average precipitation in 2020, which led to the prioritization of other water uses over electricity generation.[16]

Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, the SHP installed capacity slightly increased due to access to more accurate data (Figure 3).

Figure 3. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in Guadeloupe (MW)**



Sources: DEAL,[14] Region Guadeloupe,[15] *WSHPDR 2013*,[17] *WSHPDR 2016*,[18] *WSHPDR 2019*[19]

The SHP potential is estimated to be 33 MW for an average annual generation of 98 GWh. This potential is concentrated in Basse-Terre, with the development potential being limited by the boundaries of the Guadeloupe National Park. The national park stretches across most of Basse-Terre, therefore, power plants may only be sited on its perimeter. Overall, the development of hydropower in Guadeloupe is constrained by many factors, including energy regulations, in particular, environmental regulations, as well as by the high costs associated with land clearing and connection to the grid. Taking these factors into account, it is estimated that only 25 MW of hydropower capacity can be developed under ideal conditions, for a possible annual generation of 75 GWh.[15,20]

Table 1. **List of Installed Small Hydropower Plants in Guadeloupe**

Name	Installed capacity (MW)	Operator	Launch year
La Rose	2.50	VALOREM	2016
Bovis	0.20	VALOREM	2008
Valeau	0.20	VALOREM	2006
Schoeler	0.07	VALOREM	2004
Saint Sauveur	0.07	VALOREM	2003
Clairefontaine	0.20	VALOREM	2002
Gaschet	0.20	VALOREM	2002
Letaye	0.20	VALOREM	2002
Bellevue	0.11	VALOREM	2002
Partiteur 1 & 2	0.57	VALOREM	1995
Bananiers	2.50	EDF	1994
Carbet	4.50	VALOREM	1993
RN2	0.20	VALOREM	–
Dongo	0.07	VALOREM	–

Source: DEAL,[14] VALEMO,[21] Region Guadeloupe[22]

Most SHP plants in Guadeloupe are operated by VALOREM, a renewable energy operator that entered the country's market in 2018. Initially the company was involved in the wind power sector, but in 2019 expanded into hydropower by acquiring 14 SHP plants from Force Hydraulique Antillaise SAS (FHA).[21]

RENEWABLE ENERGY POLICY

In recent years, Guadeloupe has adopted measures for the development of renewable energy sources. As of 2021, its electricity mix consisted of 23 per cent of renewable energy.[8] A range of projects have been developed to size and install renewable power plants in the country.[10] In 2017, the 2016–2023 Multi-Year Energy Programme (PPE) was approved, replacing the Regional Plan for Renewable Energy and the Rational Use of Energy (PRERURE). The PPE aims to reduce final energy consumption by 10 per cent by 2023 and limit the increase in electricity consumption demand to +4 per cent in the same year. It also highlights the objective to achieve a 50 per cent share of renewable energy in final energy consumption, develop 261 MW of additional renewable energy capacity by 2023 (relative to 2015) and achieve energy independence by 2030.[23]

The current technology and the regulatory environment limit the future expansion and upgrades of existing hydropower facilities. While the PPE encourages proposals for enhancing existing production capacities or developing new ones, the PPE is more aimed at strengthening systems to manage energy demand and developing other renewable energy sources, whereas for hydropower no new developments are planned.[17,23]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The main barriers to further development of SHP in Guadeloupe are the following:

- Environmental standards are strict and the construction of new SHP plants may be slow to ensure compliance;
- Significant water resources for micro-and small-scale hydropower are located in the National Park, which is a protected area;
- High costs for grid connection and area clearing;
- There is more interest in the development of other renewable energy sources, rather than SHP, as after multiple feasibility studies, it was concluded that solar, geothermal and wind power are the most cost-effective alternatives.

The enabling factors for SHP development in Guadeloupe include:

- The hydropower sector development, including optimization of existing capacities, is actively encouraged in the PPE;
- Guadeloupe has IPP experience in renewable energy project development.

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Haiti

Pierre Kenol Thys, Inter-American Development Bank; and Laura Stamm, International Center on Small Hydro Power (ICSHP)

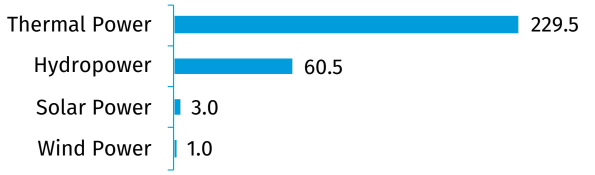
KEY FACTS

Population	11,402,533 (2020)[1]
Area	27,750 km^2 [2]
Topography	The terrain is predominantly rugged with approximately two-thirds of the territory lying at elevations above 490 metres. The coastline is largely irregular with rocky shores and cliffs. The major mountain ranges run in an east-west orientation such as the Northern Massif, the Matheux Mountains that extends into the Trou d'Eau Mountains on its eastern end, and the Massif de la Hotte that extends into the eastern Massif de la Selle. The country's highest peak, Mount La Selle, reaches 2,674 metres and is located in the south-eastern Massif de la Selle. Two minor ranges, the Cahos and Noires Mountains are located in the central region and surround the Central Plateau, a flat region with an average elevation of 300 metres. With a long fault line crossing the southern part of the country and passing just south of the capital city Port-au-Prince, the country is subject to periodic seismic activity.[2]
Climate	Haiti generally has a tropical climate. Average temperatures vary greater between altitudes than throughout the year. Near sea level, temperatures range from 25 °C in January and February to 34–36 °C in July and August. In higher elevations, temperatures average 16 °C and frost can occur during the winter months. [2]
Climate Change	As an island state in the Caribbean, the country's largest climate risks are the rising of sea levels and surges in natural disasters. In the upcoming decades, an increase in the prevalence and intensity of hurricanes and tropical storms is anticipated. At the same time, overall rainfall is expected to decrease, as it already has been decreasing at a rate of 5 mm per month per decade since 1960. Additional concerns are that the tendencies of coastal erosion, landslides and droughts will most likely intensify.[3,4]
Rain Pattern	Annual rainfall varies between regions and elevation. The northern and eastern mountainous regions experience the most rainfall with an average of 1,200 mm per year. Western regions with low elevations and La Gonâve Island receive closer to 550 mm per year. Generally, the wet season is between May and November, but some regions experience a minor dry season between June and August.[4]
Hydrology	The Artibonite is the longest river on the island at 280 kilometres. It begins in the Northern Massif (the Cordillera Central) in the western Dominican Republic and flows south-westwards along the border with Haiti, draining into the Gulf of La Gonâve. Its tributaries flow eastwards and southwards through the Central Plateau. In the east, the Artibonite was impounded as Lake Péligre. Most other rivers are short and not navigable.[2]

ELECTRICITY SECTOR OVERVIEW

As of 2020, the total installed capacity in Haiti was reported to be 294 MW but no accurate official data are available. Approximately 78 per cent of the total, or 229.5 MW, was from thermal power plants, over 20 per cent, or 60.5 MW, was from hydropower and the remaining 2 per cent was from 3 MW of solar power and 1 MW of wind power (Figure 1).[5] A large majority of the installed capacity serves the country's capital and metropolitan area including the three largest thermal power plants — Carrefour I (50 MW), Carrefour II (34 MW) and E-Power (34 MW) — and the largest hydropower plant, Péligre (54 MW).[6,7] Another major thermal power plant is planned to be constructed in Carrefour and the large Varreux thermal power plant (68 MW) is in need of renovation. While these constructions take place, a Turkish company has been approved to install two barges, or floating power plants, with a combined capacity of 115 MW, near Varreux and Cap-Haitien.[8] Additionally, in 2021, funding was secured to be provided by the United States Agency for International Development (USAID) and the Inter-American Development Bank (IADB) to construct two new solar power plants in Carrefour with capacities of 8 MW and 4 MW.[9]

Figure 1. **Installed Electricity Capacity by Source in Haiti in 2020 (MW)**



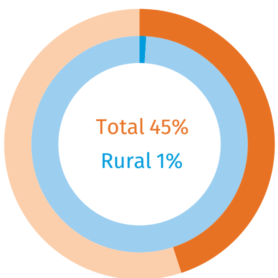
Source: CCREEE[5]

Due to infrastructural deterioration and technical inefficiencies, the actual available capacity is lower than what is installed and much of what is generated is lost. Total electricity generated in Haiti in 2020 was 2,199 GWh. Of this, approximately 380 GWh was sold and the remaining 1,319 GWh, almost 60 per cent, was considered lost.[5] This is due to widespread inefficiencies, and also to illegal connections to the grid that are not metered and, therefore, unbilled.[10]

Many households and businesses in Haiti generate their own electricity, most commonly with diesel units. While some use the generators as a back-up during blackouts, many have disconnected completely from the grid and fully rely on their own generators. The total capacity of electricity self-generated off the grid is unknown, but it exceeds the electricity generated on-grid. In 2017, it was estimated that over 75 per cent of total electricity generated within the country was from self-generation.[10]

In 2019, the overall electrification rate in Haiti was approximately 45 per cent and in rural areas it was just 1 per cent (Figure 2), the lowest in the western hemisphere.[11] Additionally, for the people that do have access to electricity, it is often only for some hours of the day rather than a 24-hour connection.

Figure 2. **Electrification Rate in Haiti in 2019 (%)**



Source: World Bank[11]

The electricity grid in Haiti consists of a number of isolated grids. Outside of the metropolitan area, there are 10 regional grids that serve the larger towns and nearby areas, as well as approximately 30 village-level grids.[12]

The principal company in the sector is Electricity of Haiti (EDH). By a decree of 20 August 1989 EDH was granted monopoly rights to generate, transmit, distribute and sell electricity across the country, but also allowed to outsource electricity production to independent power producers (IPPs). Another decree issued in 2006 allowed local communities not served by EDH to contract independent enterprises to provide electricity services, which fostered the development of micro-grids in the country. Historically there was no regulatory agency overseeing EDH activities until the National Authority for the Regulation of the Electricity Sector (ANARSE) was established in 2016, whose purpose is to guide the development of the electricity sector, in particular, through increasing the private sector involvement.[12]

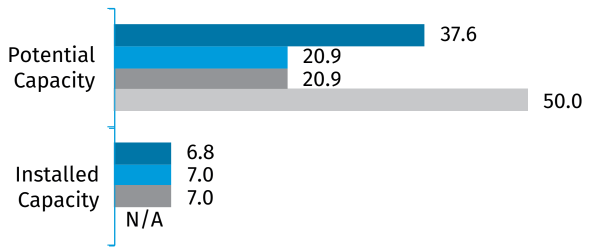
Electricity tariffs vary by consumer type. For residential customers the total tariff is 0.28 USD/kWh, for commercial customers it is 0.37 USD/kWh, for industrial customers it is 0.39 USD/kWh and for street lighting it is 0.37 USD/kWh.[5]

SMALL HYDROPOWER SECTOR OVERVIEW

There is no official definition of small hydropower (SHP) in Haiti. For the purposes of this chapter, all hydropower plants up to 10 MW will be classified as SHP.

In 2018, the total installed SHP capacity up to 10 MW in Haiti was 6.81 MW (Table 1).[13] Considering additional potential sites found in feasibility studies, total SHP potential in Haiti is 37.56 MW. Compared to the results of *the World Small Hydropower Development Report (WSHPDR) 2019*, installed capacity has slightly decreased and potential capacity has increased, both due to new available data (Figure 3).

Figure 3. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in Haiti (MW)**



Sources: Mitchell,[13] *WSHPDR 2019*,[14] *WSHPDR 2016*,[15] *WSHPDR 2013*[16]

There are currently eight hydropower plants in Haiti, all of which are operated by EDH. Seven plants are small-scale, while the only large-scale hydropower plant, the 54 MW Péligre plant, is the oldest hydropower plant in the country. Its first turbine out of three was commissioned in 1971 and it took three more years to complete the other two turbines. The most recently commissioned hydropower plant is an 11 kW micro-hydropower plant installed in the small community called Magazen, in the Nord-Est province, in 2016. This plant supplies electricity to 74 families.[14]

Over the years, the available capacity of the hydropower plants has decreased due to ageing equipment and lack of maintenance. In July 2018, with more than USD 100 million provided by the Inter-American Development Bank (IDB), the KfW Development bank and the Organization of the Petroleum Exporting Countries (OPEC) Fund for International Development, the biggest source of renewable energy in the country, the Péligre hydropower plant, regained its initial capacity of 54 MW.[14]

Table 1. **List of Existing Small Hydropower Plants in Haiti**

Name	*Location (region)*	*Installed capacity (MW)*
Drouet	Le Grand Nord	2.50
Saut Mathurine	Le Grand Sud	1.60
Délugé	Le Grand Nord	1.10
Caracol	Le Grand Nord	0.80
Gaillard	Le Grand Sud	0.50
Onde-Verte	Centre Ouest	0.30
Magazen	Nord-Est	0.01
Total		**6.81**

Source: Mitchell[13]

Table 2. **List of Selected Hydropower Potential Sites in Haiti**

Name	*Location (region)*	*Capacity (MW)*
Guayamouc GU3.5	Centre	3.41
Roche Plate	Centre	2.57
Grande Anse BG15.4	Grand'Anse	2.48
Guayamouc GU25.7	Centre	2.13
Trois Rivieres TR28	Nord-Ouest	1.78
La Theme LA1.6	Centre	1.35
Grand Anse GA4.1	Grande'Anse	1.21
Deluge-Lanzac	Artibonite	1.18
Momance	Ouest	1.12
Grand Anse BD8.6	Grande'Anse	1.06
Grand Anse GA35.4	Grande'Anse	0.97
Cazale 1	Ouest	0.89
Samana	Centre	0.78
Fer a Cheval FC8.5	Centre	0.74
Trois Rivieres TR78	Artibonite	0.73
Grand Riviere du Nord GN30.3	Nord	0.72
Riviere Grise G31.0	Ouest	0.72
Pichon 2	Sud-Est	0.68
Saut d'Eau	Centre	0.67
Bouyaha B11	Centre	0.63

Source: Mitchell[13]

In addition to the existing SHP capacities, there are a significant number of sites identified with SHP potential that can be harnessed. According to the most recent feasibility study carried out by the Ministry of Public Works, Transport and Communication (MTPTC), there are 36 potential SHP sites ranging in capacity from 0.13 MW to 3.41 MW and with a combined untapped potential of 30.75 MW. The 20 potential sites with the largest capacities are shown in Table 2.[13]

RENEWABLE ENERGY POLICY

The development of the country's energy sector follows the Strategic National Plan for the Development of Haiti (SPDH), which envisages improving on-grid electricity services in urban areas and surroundings and supporting off-grid electrification in rural areas. The National Development Plan for the Energy Sector (2007–2017) recommended the promotion of renewable energy sources (wind power, solar power, biofuels) and the creation of an additional capacity from renewable energy sources of some 40 MW.[17] The plan also included objectives to increase electricity service for customers to have access 12 hours per day, to improve the regulatory role of the state and to create an environment that attracted foreign and domestic investment in the sector.[18] However, the 2010 earthquake, which damaged or destroyed a great number of electricity facilities, rendered the plan out-of-date and it has not been updated yet.

Nonetheless, the Government remains committed to the development of renewable energy sources in the country. In the country's First Nationally Determined Contribution of 2015, it set renewable energy goals for 2020 and 2030. By 2020, the goal was to install additional 37.5 MW in hydropower, which has not been achieved as of 2022. Conditional goals for 2030 include installing 20 MW of biomass, 30 MW of solar power, 50 MW of wind power and to add an additional 60 MW of hydropower, so that 47 per cent of the country's electricity sector is generated using renewable energy.[19]

In the country's 2017–2018 budget, measures for the promotion of renewable energy projects, particularly solar power, were introduced, including the elimination of import tariffs and duties on solar equipment. One of the objectives for the 2017–2018 fiscal year was to pursue the installation of solar power facilities across the country, particularly in areas with limited infrastructure, with a minimum of one installation per community.[20]

In 2017, the World Bank approved two grants for a total amount of USD 35 million, which will fund two projects in Haiti, Renewable Energy For All and Haiti Modern Energy Services For All. The projects aim to improve access to electricity and to scale up investments in renewable energy in underserved rural and urban areas. In particular, they will help:

- Improve the environment for private investment in renewable energy;
- Expand the access for rural households through leveraged investments in micro- and mini-grids and village level systems;

- Strengthen the capacity of local institutions and develop awareness of local communities on how to use renewable energy;
- Finance private operators, non-governmental and community organizations to provide solar lanterns and individual and home-based solar systems.[21]

As per the Decree on the Management of Environment and the Regulation of Citizen Conduct for Sustainable Development of 2005, all policies, plans and projects that would have a negative impact on the environment are subject to an environmental impact assessment (EIA). It also provides legal framework for various levels of government and their responsibilities towards the environment.[18]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The barriers hindering the development of SHP in Haiti include:

- Absence of a single decision-making authority and lack of coordination among government agencies and ministries;
- Absence of a legal framework aiming to facilitate private investment and technical rules facilitating connection between local grids;
- Limited funds for the construction of hydropower plants. The initial investment for the construction of a plant is considerably high, therefore, developers can be reluctant to invest;
- Lack of transmission infrastructure outside the capital metropolitan area and the cost of electricity system development is high.[14]

The key enablers for development of SHP in Haiti include:

- Most of the SHP potential is untapped and many sites have already been identified with their respective capacities;
- Being the least electrified country of the region, the necessity of developing power plants and supplying electricity is crucial, especially in rural or remote areas.

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Jamaica

Kimberly Lyon, World Bank

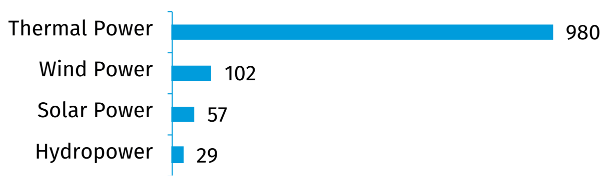
KEY FACTS

Population	2,734,092 (2019)[1]
Area	10,991 km^2[2]
Topography	The terrain of Jamaica is mostly mountainous, with a narrow, discontinuous coastal plain. The highest point is the Blue Mountain Peak at 2,256 metres above sea level and the lowest point is the Caribbean Sea.[2]
Climate	Jamaica has a tropical climate, which is influenced by the North-East Trade Winds, with a temperate climate in the interior. Average temperatures historically range from 24 °C to 27°C, varying with elevation and proximity to the coast.[3]
Climate Change	Jamaica has not experienced a significant increase or decrease in overall rainfall, but total annual precipitation is projected to decline starting in the mid-2020s due to climate change, with an onset of a more pronounced drying trend in the mid-2030s. The country is also grappling with the consequences of sea level rise. Current trends are projected to continue with possible temperature increases of 0.82-3.09 °C by the end of the century.[3]
Rain Pattern	Jamaica has a bimodal rainfall pattern, which translates into a dry season lasting from December to March and a rainy season from April to November. The mountainous interior generally receives annual rainfall in excess of 1,700 mm and the eastern part of the island receives up to 5,000 mm or more. The northern and southern coasts are significantly drier with the plains of the south receiving on average 1,000 mm of precipitation or less.[3]
Hydrology	The water resources of Jamaica consist of groundwater, captured in both limestone and alluvial aquifers, and surface water from over 100 rivers and streams. The central mountain ranges divide the catchment areas for rivers, which drain either to the northern or to the southern coasts. The island is divided into 10 hydrological zones. The limestone and alluvium aquifers provide 84 per cent of the country's freshwater resources, while the remaining 16 per cent is provided by surface water. The exploitable water resource is estimated at 3,930 MCM/year.[4,5] The main rivers include the Black River, Great River, Rio Cobre, Rio Grande, Rio Minho, Wagwater River and Yallahs River.[6]

ELECTRICITY SECTOR OVERVIEW

Electricity generation in Jamaica is dominated by fossil fuels with a growing contribution from renewable energy. At the end of 2019, Jamaica had 1,198 MW of available generation capacity, which generated 4,430 GWh of power (Figure 1). Of this total, the Jamaica Public Service (JPS) generated 1,229 GWh from steam and diesel, 1,055 GWh from gas and 155.2 GWh from small hydropower (SHP). Additionally, JPS purchased a further 1,990.3 GWh from independent power producers (IPPs) powered by wind power, solar power and oil.[7,8]

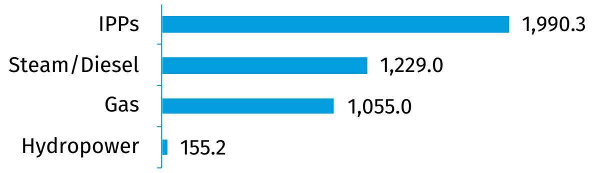
Figure 1. **Annual Electricity Generation by Source in Jamaica in 2019 (GWh)**



Source: JPS[7,8]

By the end of 2020, with the retirement of older units, there was 1,168 MW of available generation capacity.[7,9] Renewable sources made up almost 18.5 per cent of existing capacity and the remaining 81.5 per cent was fossil fuel-based, specifically, liquefied natural gas (LNG), heavy fuel oil (HFO) and automotive diesel oil. In 2020, the national power utility JPS continued with its plans to retire older fossil fuel plants and convert remaining steam generation assets to run on LNG. Thus, at the end of 2019, the island had 1,010 MW of thermal power capacity, while in 2020 this figure was reduced to 980 MW.[7] Wind power is the largest source of renewable energy at 102 MW, followed by solar power and hydropower at 57 MW and 29 MW, respectively (Figure 2).[10]

Figure 2. **Installed Electricity Capacity by Source in Jamaica in 2020 (MW)**



Source: JPS,[7] MSET[10]

The share of the population in 2017 with access to electricity stood at 94 per cent nationally with 98 per cent in the Kingston Metropolitan Area, 93 per cent in other towns and 91 per cent in rural areas. The vast majority of households get their electricity from the grid with only 0.1 per cent getting electricity from off-grid solar.[11] According to the World Bank, in 2019 over 99 per cent of the country's population had access to electricity, including 100 per cent in urban areas and almost 99 in rural areas.[12,13,14]

JPS is a vertically integrated power utility. It fully controls transmission and distribution of electricity on the island and owns 47 per cent of the power generation capacity, purchasing the remainder of its supplied electricity from IPPs, including Jamaica Energy Partners (JEP), Jamaica Private Power Company (JPPC), Jamalco and Wigton Wind Farm. The JPS was fully state-owned until 2001 when the Government of Jamaica divested 80 per cent of its shares to foreign investors. A small group of individuals hold 0.1 per cent of the JPS shares. In 2019, the Government announced its intention to list its remaining 19.9 per cent interest on the stock market. As of early 2021, the Government still retained its shares in the JPS.[9,15]

New generation capacity is added to the network through a competitive process and over 2015–2020, 117.3 MW of renewable energy capacity (wind power and solar photovoltaics (PV)) were added to the grid. The country's 2030 target for renewable energy penetration is 20 per cent of the total energy mix and 30 per cent of electricity generation.[10]

Electricity demand is expected to steadily grow over the coming decades with a forecasted annual growth rate of 1.3–1.6 per cent until 2035. By 2035, demand is projected to reach 5,865 GWh. Demand growth for both residential and commercial customers is expected to be driven largely by overall economic growth. JPS's load factor is assumed to remain constant at 78 per cent.[10]

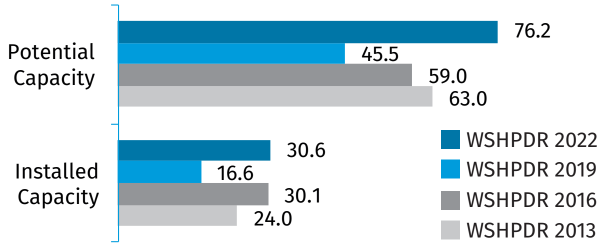
The average electricity tariff in Jamaica has trended downwards in recent years from 0.35 USD/kWh in 2013 to approximately USD0.27/kWh in 2020.[16,17] Nonetheless, it remains high due to the country's reliance on older, less efficient HFO generators that run on costly imported fuel as well as high losses in the transmission and distribution network. Because of its dependence on fuel imports, Jamaica remains very exposed to international price fluctuations. These factors, together with meeting the climate commitments, underpin the Government of Jamaica's strategy to increase the penetration of renewable energy in the energy mix and to transition the fleet of oil- and diesel-powered assets to run on LNG.[10,16]

The electricity sector is regulated by a multi-sector regulator, the Office of Utilities Regulation, which determines the electricity tariffs and oversees the net billing programme aimed at increasing renewable energy generation by small-scale intermittent sources (wind power and solar PV). With the rise of self-generation and other developments in the electricity sector, including the introduction of electric vehicles and the commissioning of a hybrid energy storage system, several new categories of tariffs were introduced in the JPS tariff determination for the period up to 2024. These include a distributed energy resource (DER) tariff for self-generation customers, an electrical vehicle tariff and a wheeling tariff.[17]

SMALL HYDROPOWER SECTOR OVERVIEW

SHP is not defined in Jamaican law or policy, but the threshold of 10 MW is commonly used by energy sector professionals and Government officials, with facilities below 1 MW considered mini-hydropower. All existing hydropower facilities and all but one proposed facility — the Mahogany Vale site — are under 10 MW.

Figure 3. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in Jamaica (MW)**



Source: JPS,[7] MSET,[10] *WSHPDR 2019*,[19] *WSHPDR 2013*,[20] *WSHPDR 2016*[21]

There are eight existing hydropower plants in Jamaica (Table 1), all owned and operated by JPS. Together, these have an installed capacity of 30.6 MW and an annual generation of 152,612 MWh.[7,10] The existing hydropower fleet is fairly old with several facilities constructed before the country's independence in 1962. However, most facilities have been rehabilitated since the 1990s.[18] The most recent addition to the fleet is an extension project with a second powerhouse at the Maggoty Falls facility, which came online in 2014. The original Maggoty Falls facility was commissioned in 1966. Thus, no new SHP plants have been commissioned in Jamaica since the *World Small Hydropower Development Report (WSHPDR) 2019*. The change in the reported installed capacity is due to the fact that in the previous edition the

Maggoty Falls plants were counted as one and, hence, were excluded from the total due to their combined capacity exceeding 10 MW. However, the two Maggoty Falls plants have separate powerhouses and are treated by JPS as separate projects. The potential capacity estimate has also increased compared to the previous edition, based on new data on available sites (Figure 3).

Table 1. List of Existing Small Hydropower Plants in Jamaica

Name	Location	Capacity (MW)	Head (m)	Plant type	Operator	Launch year
Maggoty Falls Extension B	St. Elizabeth	7.2	88.4	Run-of-river	JPS	2014
Rio Bueno B	Trelawny	1.1	N/A	Run-of-river	JPS	1989
Ram's Horn	St. Andrew	0.6	N/A	Run-of-river	JPS	1989
Constant Spring	St. Andrew	0.8	N/A	Run-of-river	JPS	1989
Maggoty Falls A	St. Elizabeth	6.0	88.4	Run-of-river	JPS	1966
Lower White River	St. Ann	4.8	115.2	Run-of-river	JPS	1952
Roaring River	St. Ann	3.8	152.4	Run-of-river	JPS	1949
Rio Bueno A	Trelawny	2.5	89.9	Run-of-river	JPS	1949
Upper White River	St. Ann	3.8	70.1	Run-of-river	JPS	1945

Source: JPS,[7] USACE[22]

Thirteen potential SHP sites have been studied for full-scale feasibility and deemed feasible. One site, Morgan's River, was studied at the pre-feasibility level but did not progress to full feasibility. The Rio Cobre (Angels) site is located at an existing irrigation weir operated by the National Irrigation Commission Ltd.[23,24,25] In the *WSHPDR 2019*, the 0.8 MW Dry River site was included in the list of potential SHP projects, however, in the current edition it has been removed as it was determined as not viable in a 2013 analysis by the Ministry of Science, Technology, Energy and Mining. Furthermore, the potential reservoir-based project Mahogany Vale with an estimated potential capacity of 50 MW has been foregone in favour of six small run-of-river projects in the same basin: Spanish River, Negro River, Yallahs River, Green River, Back Rio Grande and Swift River. The Back Rio Grande site (with a potential of 10–28 MW) appears to have been foregone in favour of four smaller projects: Swift River, Rio Grande 1, Rio Grande 2 and Back Rio Grande 2. Table 2 shows the available potential SHP sites.

Compared to other countries, the hydropower potential of Jamaica is considered low.[29] Based on the existing installed capacity and the identified potential sites, the country's economic SHP potential capacity and generation stand at 76.2 MW and 347 GWh per annum, respectively. The technical potential capacity and generation are estimated at over 80 MW and 600 GWh per annum, respectively.[30,31]

All the potential sites identified have been studied with a view to connecting them to the existing transmission and distribution network. There is little scope for off-grid SHP investments, but the law permits the development of micro-grids for rural electrification if JPS waives its right to provide service in a particular geography.[32]

Table 2. List of Potential Small Hydropower Projects in Jamaica

Name	Location	Potential capacity (MW)	Head (m)	Type of site
Great River	St. James	8.0	N/A	New
Spanish River	Portland	7.8	N/A	New
Martha Brae	Trelawny	4.4	N/A	New
Back Rio Grande 2	Portland	4.0	83.13	New
Swift River	Portland	2.9	54.9	New
Green River	St. Thomas	2.8	224.8	New
Morgan's River*	St. Thomas	2.7	N/A	New
Yallahs River	St. Thomas	2.6	N/A	New
Negro River	St. Thomas	2.3	N/A	New
Laughlands Great River	St. Ann	2.0	N/A	New
Wild Cane	St. Thomas	1.9	559.6	New
Rio Cobre (Bog Walk)	St. Catherine	1.5	N/A	New
Rio Cobre (Angels)	St. Catherine	1.0	7.8	Refurbishment
Rio Grande 1	Portland	0.9	9	New
Rio Grande 2	Portland	0.8	13.4	New

Source: MSET,[10,26] USACE,[22] Makhijani,[27] Williams[28]

Note: The project did not progress to the full feasibility study after the pre-feasibility study.

Efforts to promote SHP increased in the 2010s with the commissioning of pre-feasibility and feasibility studies for 11 sites ranging from 0.8 MW to 7.8 MW. There were plans to develop business plans for six of these sites to support their promotion to potential investors. However, in 2020, the Petroleum Corporation of Jamaica, the public entity responsible for energy planning and promotion, was dissolved and these responsibilities were transferred to the Ministry of Science, Energy and Technology.[33,34] The Ministry's latest Strategic Plan, covering the period of 2021–2025, affirms the Government's commitment to promoting renewable energy investments, including in SHP.[35]

The Government has demonstrated a preference for smaller hydropower projects over larger projects, considering potential social and environmental impacts as well as impacts on high-value tourism assets. This is evident from the decisions to pursue detailed investigation of multiple smaller projects in locations where there is potential for larger plants, specifically the proposed Mahogany Vale and Back Rio Grande projects.

SMALL HYDROPOWER PROJECTS AVAILABLE FOR INVESTMENT

There are several SHP projects available for investment above 1 MW that the Government intends to develop business plans for with the intention of investment promotion (Table 3).[33]

Table 3. **List of Selected Projects for Small Hydropower Projects Available for Development in Jamaica**

Name	*Location*	*Potential capacity (MW)*	*Head (m)*	*Type of site*
Spanish River	Portland	7.8	N/A	New
Martha Brae	Trelawny	4.4	N/A	New
Swift River	Portland	2.9	54.9	New
Laughlands Great River	St. Ann	2.0	N/A	New

Source: GoJE[33]

RENEWABLE ENERGY POLICY

Jamaica has a National Energy Policy covering the period from 2009 to 2030, which is aligned with the country's National Development Plan, Vision 2030. The aim of the plan is to create and advance a modern, efficient, diversified and environmentally sustainable energy sector, focused on diversification of the energy base towards indigenous sources of energy and clean technologies. The National Energy Policy is technology-neutral and promotes all renewable energy sources, including solar power, wind power, hydropower and biofuels.[18]

In 2020, the Government completed its Integrated Resource Plan (IRP), a 20-year roadmap for the country's electricity investment landscape. The IRP envisions 32 per cent of electricity generation by 2030 and 50 per cent by 2037 to be met with renewable energy sources. A total of USD 2.8 billion of investment is anticipated over the life of the IRP.[10]

The IRP also discusses the evolution of the national grid to accommodate higher integration of variable renewable energy sources with the ultimate goal of distributed markets for energy. However, the planning process for integrated distribution is only nascent, and the Government anticipates investing in further study and improvement of the integrated distribution planning framework. At present, any new investments in SHP would take the form of an IPP with a power purchase agreement with the JPS, the single buyer whose licence obligates it to purchase electricity from IPPs and persons with net billing arrangements.[32]

Over the planning horizon of the IRP, 485 MW of private power capacity has been identified for retirement and replacement, coinciding with their power purchase agreement expiration. Most of these are HFO-fuelled and JPS has a "right of first refusal" to do these replacements if it can be done more cheaply than by the proposed developer.[10] For JPS, the current allowed pre-tax weighted average cost of capital is set at 13.22 percent and for IPPs it is 11.16 per cent. At present, there are no feed-in tariffs, but the law empowers the Ministry with responsibility for energy, in consultation with the Office of Utilities Regulation, to set feed-in tariffs. There are no differentiated electricity prices based on technology or location.[32]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

According to the IRP, Jamaica is targeting 74 MW of new capacity to come from hydropower, waste-to-energy and/or biomass by the year 2025, increasing the share of hydropower in the generation mix from 2.8 per cent in 2020 to 4.4 per cent in 2037.[10]

All recent renewable energy investments to date have been made either fully by, or with significant participation of, the private sector, hence, it is not likely that the feasible potential SHP sites will be developed in the near term without a private sponsor. As JPS has indicated, it is not interested in pursuing further SHP developments and the Government will be targeting other local or foreign investors to implement these projects.[36]

New SHP projects would be governed by the same legislation and regulations as other energy technologies. There are no provisions in the Electricity Act specific to hydropower of any size. The licensing process for SHP involves securing the necessary land access rights; environmental permits issued by the National Environment and Planning Agency; a licence from the Water Resources Authority to use surface water; a power purchase agreement with JPS; a permit for interconnection, issued by the Office of Utilities Regulation; as well as permits from municipalities in which the generation assets would be located.[10,27]

COST OF SMALL HYDROPOWER DEVELOPMENT

A 2013 study by the Government indicated an average investment cost for SHP at USD 3.5 million per MW installed.[26] Investment costs of six recently studied SHP sites showed an average estimated investment cost of USD 4 million per MW installed or USD 1.28 million per GWh of energy produced. The most recently implemented project, the Maggotty Falls extension was completed in 2014 with an investment cost USD 36 million, which corresponds to approximately USD 5 million per MW installed.[37]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

The IRP indicates that the Government intends to analyze and develop incentives for SHP, however, such incentives have not been specified at this time. Jamaica has a vibrant financial sector, including a growing equities market and several commercial banking options more generally. There have been initiatives in past years, supported by international partners such as the World Bank, to incentivize renewable energy investments through credit lines.[38] Commercial banks have also made lower-interest loans available to small and medium enterprises and households for renewable energy investments. Several of the recent renewable energy installations have been made by overseas investors, qualifying for financing from foundations as well as development financing from their Governments.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

The intensity and frequency of extreme rainfall events has shown an increasing trend over the last 70 years. While the whole island has experienced a small increase in total annual rainfall, variability has also increased with more consecutive wet days and dry days and more days recording extreme rainfall values. Portland, where several potential SHP sites are located, and Westmoreland have experienced the largest changes. Going forward, climate models project that average rainfall will decrease in Jamaica with a drying trend that will begin affecting the island in the mid-2020s. The island is projected to be up to 4 per cent drier by the 2030s and up to 10 per cent drier by the 2050s.[3] This will negatively impact river flows and decrease hydropower generation. Climate change and longer droughts are also expected to contribute to increased energy demand, though projections for energy demand are still largely driven by economic growth assumptions. All existing and proposed hydropower sites are run-of-river and thus have no inter-seasonal or inter-annual storage to help manage variability in flows. Future investments, particularly on the island's major rivers, will need to take into account the expected increase in extreme rainfall events.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

There has been very little activity in the SHP sector since the last set of Government-developed projects in the 1980s. Driven by efforts to lower the cost of electricity and transition the portfolio towards low-carbon indigenous sources of electricity, there has been a renewed interest in SHP development with new and updated studies having been completed in recent years.

The main barriers to SHP development in Jamaica are:

- Significant capital costs, which often exceed those for commercial-scale solar PV and wind power, and licensing requirements that involve a wider range of actors and regulators such as for the acquisition of land and water rights.
- Hydropower is widely perceived by sectoral actors as being very technically complex. The current sole operator of SHP assets in Jamaica is also not interested in further SHP development, instead favouring larger capacity installations with other technologies.
- Much of the knowledge of SHP development and operation is concentrated with JPS as the sole operator of SHP currently. Due to the limited activity in the sector over several decades, local contractors have virtually no experience in this specialized area. The island is heavily dependent on international engineers and consultants for SHP studies.
- Natural hydrologic variability. Many potential projects are located in the rainiest parts of the island, where the floods are so significant as to require significant infrastructure for safe control of releases.
- Disruptions in renewable energy planning and promotion. With the dissolution of the entity primarily responsible for energy planning in 2020 and the transfer of these responsibilities to the Ministry, activities aimed at promoting SHP development have been delayed or altered, including the development of business plans for selected SHP sites.

Nonetheless, in recent years, the enabling environment for SHP has become more favourable:

- The Government has invested considerably in new technical studies for SHP with the intention to develop business plans to support the promotion of selected sites as well as to develop an incentive structure to attract investors. Policy directives heavily favour indigenous renewable energy technologies, including SHP.
- The energy market of Jamaica is becoming more liberalized with the introduction of the 2015 Electricity Act (replacing the previous law enacted more than 125 years ago) and new licence structures.
- The Government has ambitious plans to modernize the energy system and significant investments in grid modernization have already been made by JPS.

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Puerto Rico

Davy Rutajoga, International Centre on Small Hydro Power (ICSHP)

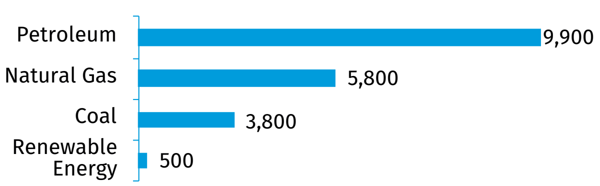
KEY FACTS

Population	3,193,694 (est. 2019)[1]
Area	8,870 km^2 [2]
Topography	Puerto Rico can be split into three physiographic zones. The mountainous interior area is formed by the Cordillera Central, the central mountain chain that transects the island from east to west. The highest point is Cerro de Punta at 1,338 metres above sea level. The second zone is the coastal lowlands that extend 10–19 kilometres inwards in the north and south. Finally, the karst region, consisting of formations of rugged volcanic rock, extends into the north of the island.[3]
Climate	The climate of Puerto Rico is tropical rainforest and temperatures throughout the year are warm to hot, between 22 °C and 25 °C. The temperatures in the southern coast are the warmest and a few degrees higher than in the north. In the central interior mountains, the temperatures are cooler than in the rest of the island.[4]
Climate Change	The 2017 Hurricane María, proven to have the greatest recorded 24-hour rainfall intensity in Puerto Rico since 1898, is among the extreme climatic events of the 2017 Atlantic Hurricane Season that can be attributed to climate change.[5] The subsequent increase in annual precipitations and rainfall intensity placed Puerto Rico first on the 2020 Global Climate Risk Index.[5] The Puerto Rico Climate Change Council reported a rise in average temperatures on the island as well as a rise in sea level and salinity of the ocean.[6] This represents a risk to the island's infrastructure as an estimated 25 per cent of it is located in coastal areas qualified as "easily flooded areas".[7] In particular, all thermal power plants on the island are located in the risky areas.[6]
Rain Pattern	The wettest month in Puerto Rico is August, with 180 mm of rain. Average rainfall varies across the island, ranging from 745 mm in the southern Isle of Maguey to 4,346 mm at Pico Del Este in the east. There is rainfall throughout the year, but it doubles from April to November, whereas the period between December and March is considered to be the driest.[8]
Hydrology	Puerto Rico has 224 rivers, with the main rivers draining the northern and southern areas. Due to the country's topography, there are no long rivers or large lakes.[7] The longest river that flows to the northern coast is the Grande de Arecibo. Other rivers include the La Plata, Cibuco, Loiza, Bayamon and Grande de Anasco.[3] Approximately 67 per cent of the surface drainage is from the central mountain ranges to the northern coast.[9]

ELECTRICITY SECTOR OVERVIEW

The main sources of energy in Puerto Rico are petroleum, natural gas and coal. In 2020, the total installed capacity was estimated at 5,839 MW, with 5,722.2 MW from fossil fuels and approximately 116.8 MW from renewable energy sources.[10] The total electricity generation of the island in 2020 was estimated at 20,000 GWh, with almost 50 per cent coming from petroleum, 29 per cent from natural gas, 19 per cent from coal and less than 3 per cent from renewable energy sources (Figure 1).[11] Average annual hydropower generation is estimated at 15.6 GWh. The natural gas is almost entirely imported as liquefied natural gas and the island has no proved reserves of crude oil or coal, both of which it imports from Colombia.[8]

Figure 1. **Annual Electricity Generation by Source in Puerto Rico in 2020 (GWh)**



Source: EIA[11]

Electricity in Puerto Rico is supplied mainly by the state-owned entity the Puerto Rico Electric Power Authority (PREPA). Average electricity tariffs for the three main groups of consumers are listed in Table 1.

Table 1. **Average Electricity Tariffs in Puerto Rico**

Type of consumer	*Average electricity tariff (USD/kWh)*
Residential	0.2326
Commercial	0.2594
Industrial	0.2288

Source: EIA[11]

In 2019–2021, the island was affected by a series of earthquakes, which culminated in a 6.4 magnitude earthquake that led to power outages by damaging electrical infrastructure. The aftershocks, estimated to recur for years after the earthquake, left two thirds of the population without power by considerably damaging the two largest power plants in Puerto Rico (EcoEléctrica and Costa Sur). As a consequence of the damage to these two natural gas-fired power plants, Puerto Rico had to shift its generation mix to rely more on petroleum, which went up to almost 50 per cent of the generation mix in 2020 from 35 per cent the previous year. Concomitantly, natural gas generation decreased to 20 per cent from 43 per cent in 2019 (Figure 2). Renewable energy generation was relatively unaffected by the earthquakes and remained stable. Power has been restored since and the island maintains an electrification rate of 100 per cent.[11]

The 2017 hurricanes damaged electrical infrastructure and led to PREPA privatizing its electricity transmission and distribution systems, as well as selling off some of its generation assets to avoid bankruptcy. The transmission and distribution systems have been operated by LUMA Energy, a private company, since June 2020.[11]

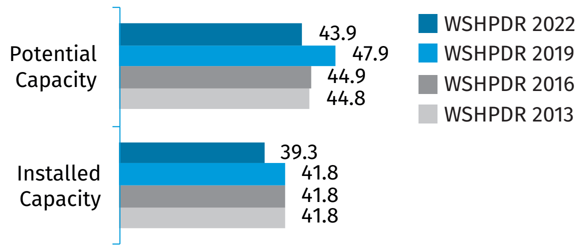
To strengthen the grid's resilience and avoid power outages, such as the ones the island experienced in the aftermath of the hurricanes of 2017, the Puerto Rico Energy Bureau issued its revised Integrated Resource Plan. Jointly with the plan, the Puerto Rico Energy Public Policy Act of 2019 (or Act No. 17 of 2019) outlines the country's commitment to sourcing 40 per cent of its electricity from renewable sources by 2025, eliminating coal-fired generation by 2028 and transitioning to 100 per cent renewable energy by 2050.[12,13]

SMALL HYDROPOWER SECTOR OVERVIEW

This chapter considers small hydropower (SHP) as plants with a capacity of up to 10 MW. There are seven SHP plants on the island with an aggregated capacity of 39.3 MW and an annual generation of 15.6 GWh. These are the 8.0 MW Yauco 2, 8.6 MW Toro Negro 1, 1.9 MW Toro Negro 2, 7.2 MW Garzas 1, 5.0 MW Garzas 2, 5.0 MW Rio Blanco and 3.6 MW Caonillas 2. However, four of these plants were inactive as of June 2021: Toro Negro 2 was offline awaiting testing, Garzas 2 was offline due to a faulty transmission line connecting it to the grid, Rio Blanco was offline awaiting replacement of the penstock and Caonillas 2 has been inactive since 1998 due to flooding from Hurricane Georges. This reduces the available capacity to 23.8 MW (Table 2).[14] Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity decreased due to the exclusion from the total of the inoperative Patillas plant (Figure 2).

The SHP sector of Puerto Rico has a potential capacity of 43.9 MW. The decrease in estimated potential capacity compared to the *WSHPDR 2019* comes after a re-evaluation of the hydropower system of Puerto Rico by the engineering firm Black & Veatch through a study commissioned by PREPA.[14]

Figure 2. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in Puerto Rico (MW)**



Source: Black & Veatch,[14] *WSHPDR 2013*,[15] *WSHPDR 2016*,[16] *WSHPDR 2019*[17]

Table 2. **List of Operational Small Hydropower Plants in Puerto Rico**

Plant name	*Installed capacity (MW)*	*Plant type*	*Operator*	*Launch year*
Toro Negro 1	8.64	Run-of-river	PREPA	1927
Yauco 2	8.00	Run-of-river	PREPA	1953
Garzas 1	7.20	Run-of-river	PREPA	1941

Source: Black & Veatch[14]

The United States Geological Survey (USGS) data have been analyzed to obtain the average discharge of the main rivers in Puerto Rico (44 in total).[18] Since all of the potential natural sites for larger reservoirs have already been used, the main potential growth area for SHP is micro-hydropower (units not exceeding 100 kW in capacity). The potential for micro-hydropower generation was determined using water flow and net head.[18] A net head range from 3 metres to 120 metres was considered due to variations from river to river or from location to location in the same river. The total micro-hydropower potential is approximately 3.1 MW (Table 3). This was the first attempt to estimate the micro-hydropower potential in Puerto Rico.[18] Not all potential sites were included in the estimate since many potential sites are not monitored.

Table 3. **Estimated Micro-Hydropower Potential in Puerto Rico**

Hydrologic unit	*Available potential (kW)*
Eastern Puerto Rico	1,148
Cibuco-Guajataca	1,067
Southern Puerto Rico	766
Culebrinas-Guanajibo	101
Total	**3,082**

Source: Izzary Rivera et al.[18]

SMALL HYDROPOWER PROJECTS AVAILABLE FOR DEVELOPMENT

The Black & Veatch study examined the need for refurbishment of the inactive plants and the improvement and modernization of the active plants. The study determined a need for a capital investment of approximately USD 140.5, million, which would result in a more than seven-fold increase in annual generation for a total potential generation of 112.7 GWh (Table 4) and a net present value (NPV) of USD 242.4 million over the 30-year period considered in the study (Table 5).[14]

Table 4. **List of Selected Small Hydropower Projects Available for Investment in Puerto Rico**

Plant name	*Installed capacity (MW)*	*Average annual generation without recommended improvements (MWh)*	*Potential capacity with recommended improvements (MW)*	*Average annual generation with recommended improvements (MWh)*	*Type of site (new/ refurbishment)*
Caonillas 2	3.60	–	1.00	5,200	Refurbishment
Toro Negro 1	8.64	5,123	8.64	26,700	Refurbishment
Toro Negro 2	1.92	85	1.92	3,300	Refurbishment
Garzas 1	7.20	2,829	7.20	12,500	Refurbishment
Garzas 2	5.04	–	5.04	8,800	Refurbishment
Yauco 2	8.00	7,523	9.00	27,300	Refurbishment
Río Blanco	5.00	–	5.00	28,890	Refurbishment
Total	**40.40**	**15,560**	**37.80**	**112,690**	

Source: Black & Veatch[14]

Table 5. **Summary of Capital Costs and Net Present Value for Small Hydropower Refurbishment Projects in Puert Rico**

Plant name	*Recommended Improvements*	*Total capital cost (USD)*	*Net present value (USD)*
Caonillas 2	New 1 MW full auto with bypass and sediment passage gates	20,300,000	(9,843,000)
Toro Negro 1	Rehabilitate small diversions with full automation, new penstocks	42,133,000	31,241,000
Toro Negro 2	Full automation and new penstocks	22,077,000	(2,510,000)
Garzas 1	Tyrolean weirs on small diversions, full automation and new penstocks	26,347,000	23,638,000
Garzas 2	Tyrolean weirs on small diversions, full automation and new penstocks	25,246,000	19,615,000
Yauco 2	Modify Yahuecas and Prieto to pass sediment, reliability improvements and full automation	3,176,000	92,008,000
Río Blanco	Restore all small diversions to service and full automation	1,200,000	88,214,000
Total		**140,479,000**	**242,363,000**

Source: Black & Veatch[14]

RENEWABLE ENERGY POLICY

Since 2010, in Puerto Rico local and foreign renewable energy businesses could choose between two incentive schemes: the Economic Incentives for the Development of Puerto Rico of 2008 and the Green Energy Fund (GEF) created by Act 83 of 2010.[19] The United States Energy Information Administration (EIA) provides some tax credits and incentives. Tax incentives include a 4 per cent fixed income rate for 15 years and a 90 per cent exemption from property taxes for 15 years. Tax credits can be up to 50 per cent to cover the expenses related to qualified research and development or to cover the cost of machinery and equipment for the generation and efficient use of energy for companies that produce their own power. Companies producing energy for domestic consumption can benefit from the GEF programme.

The GEF, worth USD 290 million and spanning over a 10-year period, supports three tiers of renewable energy projects.[20] Tier I, II and III targets correspond to residential and small businesses below 100 kW, mid-scale businesses between 100 kW and 1 MW and large-scale businesses over 1 MW, respectively.[20]

The Puerto Rico Sales and Use Tax Exemption for Solar Equipment, introduced in 2008, is a sales tax incentive that exempts taxes on solar power equipment and associated accessories and components.[21] Since 2019, the Energy Support Programme was introduced as a grant that aims to provide small and medium enterprises with USD 25,000 for the installation of renewable energy systems.[20]

Act 83 of 2010 introduced Renewable Energy Certificates (RECs). These are assets equivalent to 1 MWh generated from a green energy source. Starting in 2013, RECs could be bought, sold or transferred between entities. This enabled Puerto Rico to participate in the United States (US) renewable energy market. The RECs are also marketable abroad.[19]

The Renewable Portfolio Standard, created by Act 82 of 2010, set ambitious renewable energy production targets of 12 per cent by 2015, 15 per cent by 2020 and 20 per cent by 2035.[22] However PREPA failed to meet those targets with a total renewable energy generation reaching 3 per cent in 2020.[16] PREPA set new targets to derive 40 per cent of its electricity from renewable sources by 2025, 60 per cent by 2040 and 100 per cent by 2050.[11]

Act 57 of 2014, known as the Transformation and Energy Relief Act, created the Puerto Rico Energy Commission (PREC), an independent regulatory body overseeing PREPA's activities.[23] The commission is responsible for approving rate increases and urged PREPA to prepare a new Integrated Resource Plan aiming to optimize transparency and energy efficiency for electricity coming from fossil fuels and enable more renewable energy use at the distribution level. Under the updated Integrated Resource Plan, PREPA approved the refurbishment and modernization of the island's SHP plants.[12]

After Hurricane Maria struck Puerto Rico in September 2017, and the island's subsequent struggles to re-establish power over the territory, on 4 January 4 2018, the PREC released proposals emphasizing the role of renewable energy by establishing micro-grid installations.[17] The proposal defines that micro-grids must qualify as either renewable (at least 75 per cent of power from clean energy), combined heat-and-power or hybrid, and "shall consist, at a minimum, of generation assets, loads and distribution infrastructure". These are, by definition, owned by entities other than PREPA, but small cooperatives can interconnect with PREPA's grid by incurring a monthly fee of USD 25–250.[24] As part of the effort towards the development of micro-grids in Puerto Rico, the Rocky Mountain Institute (RMI) is collaborating with Fundación Comunitaria de Puerto Rico and Resilient Power Puerto Rico to assess the opportunity for resilient micro-grids on the island. This joint project is funded by the Rockefeller Foundation.[25]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

In Puerto Rico, SHP plants are regulated by some of the same legislation as larger hydropower projects. The main legislation and regulation documents concerning hydropower are:

- Puerto Rico Energy Public Policy Act (2019);
- Puerto Rico Electric Power Authority Act (1941);
- Puerto Rico Green Energy Incentive Law (2010).
- Legislation addressing SHP include:
- Hydropower Regulatory Efficiency Act (2013);
- Public Utility Regulatory Policies Act (1978);
- Federal Power Act (1920).

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

Many energy projects, including SHP, are funded by PREPA, which in turn receives funding from the Government of Puerto Rico and also, by extension, the US Government.[11] In addition to PREPA, the GEF provides funding for SHP projects in the form of rebates. For tier I projects (0–100 kW), rebates of up to 40 per cent of eligible costs are offered by the GEF on a first-come, first-served basis. For tier II projects (101 kW–1 MW), up to 50 per cent rebates are offered by the GEF through a quarterly competitive process.[19]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Due to increasingly frequent extreme climatic and seismic events such as the hurricane seasons of 2017 and 2019 and the series of earthquakes in 2020, electricity infrastructure in Puerto Rico has been considerably damaged. Many transmission lines were damaged, leaving a third of the population without electricity. These types of events resulting from climate change have already affected SHP in the past, with floods from Hurricane Georges damaging the Caonillas 2 plant in 1998. This plant was still awaiting refurbishment in 2021.

As most electrical infrastructure in Puerto Rico is situated in easily flooded areas, SHP plants are also threatened by the rising sea level, which could flood the island's coast. Finally, SHP plants in Puerto Rico are also affected by the limited water resources, which could worsen as irregular rainfall patterns have already been observed.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

In the short term, an increase in SHP generation could come from improvements in PREPA's existing hydropower units and also through micro-hydropower connected through net metering or in a stand-alone mode.[14]

There are, however, many barriers to SHP. The main ones include:

- A lack of finance: between PREPA and its bankruptcy, securing finance for any type of power plant will be difficult. Investment might also be difficult due to years of PREPA mismanagement;
- Limited SHP potential, compared with other renewable energy resources, in particular, solar, wind and

tidal power;
- Risk of severe weather events that could damage hydropower equipment;
- Lack of reservoir management. However, it is possible that if existing reservoirs were properly maintained, namely being dredged periodically, as well as if new generators were put in place and better water management were implemented, the potential for SHP could increase threefold;
- Limited water resources, which are used in the country mainly for human consumption;
- Some obstacles associated with micro-hydropower include little experience with this option in Puerto Rico and the division of regulatory oversight among local and federal (US) agencies, which does not present a clear permitting process for hydropower alternatives.[11,14]

Enablers for SHP development in Puerto Rico include:
- Government support for renewable energy in the form of subsidies for energy transition to renewable systems;
- Laws and regulations that support the development of SHP;
- PREPA's interest to refurbish and modernize SHP plants, including the commissioning of a study on the feasibility of refurbishment in 2021. This study produced a detailed report outlining the costs of improvement and the NPV in the long term;
- In 2021, the US Government rejoined the Paris Agreement, which implies a recommitment to investing in the fight against climate change and renewable energy, including hydropower and, by extension, SHP. With Puerto Rico being an unincorporated US territory, it stands to benefit from this recommitment to sustainable solutions.

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Saint Lucia

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KEY FACTS

Population	183,629 (2020)[1]
Area	616 km^2 [2]
Topography	An island of volcanic origin, Saint Lucia has a very rugged terrain. Jagged mountains of forested peaks and deep valleys, largely cover the interior of the country. In the south, the mountains tend to have even steeper slopes than in the north. The highest peak is Mount Gimie at 959 metres above sea level located towards the south-central region.[2]
Climate	Saint Lucia has a tropical maritime climate with little variation throughout the year. Temperatures typically range from 23 °C to 31 °C with an overall average of 27 °C at sea level. In higher elevations temperatures can dip to as low as 13 °C. While humidity remains above 70 per cent all year long, seasons are categorized by precipitation with a wet season between June and November and a drier season between December and May.[2]
Climate Change	Maximum temperatures in Saint Lucia have increased by over 1 °C since 1975 and the number of extremely hot days in a given year has also increased. This trend is expected to continue in the upcoming decades. Prevalence of hurricanes and overall windspeeds have increased but overall average rainfall per year has decreased within the past decades. As climate change continues into the future, natural disasters are expected to become more intense and the general climate is expected to become hotter and drier.[3]
Rain Pattern	Rainfall varies between seasons and elevation. Average rainfall is approximately 1,450 mm per year on the coasts near sea level and approximately 3,420 mm per year at higher altitudes in the interior. During the wet season from June to November, rain falls at a country-wide average rate of 200–250 mm per month, and between December and May usually less than 150 mm will fall per month. Occasional hurricanes are experienced during the wet season.[3,4]
Hydrology	There are 37 watersheds in Saint Lucia, of which 7 are of significance. These are the Roseau, Marquis, Cul-de-Sac, Fond D'Or, Troumassee, Cannelles and Vieux Fort Rivers. These rivers begin in the central region of high elevation and flow downwards to empty into the sea. The watersheds in the north of the island tend to be larger than those of the south, with the Roseau watershed being the largest.[4]

ELECTRICITY SECTOR OVERVIEW

At the end of 2020, total installed capacity in Saint Lucia was 91.6 MW with an available capacity of 88.4 MW that satisfied a peak demand of 59 MW. Most of the installed capacity, or 87.4 MW (over 95 per cent), was from the diesel-fuelled Cul-de-Sac power plant. A solar farm in La Tourney with an installed capacity of 3 MW and 1.23 MW of distributed solar photovoltaics (PV) rooftop panels feeding into the grid (under 5 per cent of the total) are the sources of renewable energy in the country (Figure 1).[5]

Figure 1. **Installed Electricity Capacity by Source in Saint Lucia in 2020 (MW)**

Source: LUCELEC[5]

Total electricity generation in Saint Lucia for the year 2020 amounted to 367.5 GWh, of which approximately 360.9 (98 per cent) was from diesel fuel and 6.6 GWh (2 per cent) was from solar power (Figure 2). Approximately 336.5 GWh was sold by the country's electricity company during the year. The residential sector consumed a total of 136.5 GWh and the commercial sector (excluding hotels) consumed 120.3 GWh. Hotels, usually one of the most important buyers of electricity in the country's tourism-dependent economy, consumed 51.5 GWh, which was an almost 40 per cent decrease from previous years due to the COVID-19 pandemic. The industrial sector consumed 17.8 GWh and street lighting used 10.3 GWh.[6] The sector experienced just under a 6 per cent loss of electricity for the year.[5]

Figure 2. **Annual Electricity Generation by Source in Saint Lucia in 2020 (GWh)**

Source: Department of Finance[6]

Access to electricity in Saint Lucia was over 99 per cent as of 2019.[7] St. Lucia Electricity Services Limited (LUCELEC) is the only electricity company in the country and is responsible for generation, distribution and transmission. It was created and granted sector exclusivity under the Ordinance No. 27 of 1964. The company was publicly owned until the passing of the Electricity Supply Act of 1994, which privatized its ownership but maintained its exclusivity. Currently, it is partially owned by several private entities with 10 per cent of its shares held by the Government of Saint Lucia.[8] The National Utilities Regulatory Commission (NURC) was created in 2016 as the electricity sector's regulatory body.[9]

Electricity tariffs vary based on consumer type and consumption level. Each group has a specified basic energy rate and then a standardized fuel surcharge is added. The basic rate is adjusted annually and the fuel surcharge is adjusted monthly based on global fuel prices. Table 1 shows the electricity tariffs for each type of customer as of April 2022.[10]

Table 1. **Electricity Tariffs by Consumer in Saint Lucia in April 2022**

Type of consumer	Usage	Basic energy rate (USD/kWh)	Fuel surcharge (USD/ kWh)	Final tariff rate (USD/ kWh)
Domestic	1–180 units	0.27	0.087	0.36
	> 180 units	0.29	0.087	0.38
Commercial	Low tension	0.33	0.087	0.42
	High tension (bulk)	0.31	0.087	0.40
Industrial	Low tension	0.33	0.087	0.42
	High tension (bulk)	0.31	0.087	0.40
Street lighting	All units	0.33	0.087	0.40

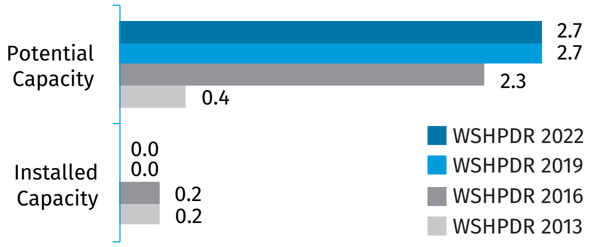
Source: LUCELEC[1]

SMALL HYDROPOWER SECTOR OVERVIEW

As there is no local definition for small hydropower (SHP) in Saint Lucia, in this chapter it is defined as plants with a capacity of up to 10 MW.

While potential capacity is estimated at approximately 2.68 MW, there were no hydropower plants in operation in the country as of 2022. There was an SHP plant in Latille Falls constructed in 2006 with a capacity of 240 kW, however, it has been years since it was severely damaged by a hurricane and is no longer in operation.[11] Most recently, a feasibility study of a potential hydropower site at the John Compton Dam on the Roseau River was carried out by a German consultancy organization in 2015. Although the study confirmed a possibility of an SHP plant of 336 kW and deemed it technically and economically feasible, no official plans to construct it have been announced as of yet.[12] Without new discoveries of potential capacity or construction of new plants in the past few years, the information remains the same since the last publication of the *World Small Hydropower Development Report (WSHPDR)* in 2019 (Figure 3).

Figure 3. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in Saint Lucia (in MW)**



Sources: *WSHPDR 2019,*[13] *WSHPDR 2016,*[14] *WSHPDR 2013*[15]

There are no local financial mechanisms specifically aimed at supporting SHP projects. However, there may be opportunities to receive support through renewable energy projects being developed by the Government of Saint Lucia.

RENEWABLE ENERGY POLICY

The country's first legislation that mentions renewable energy was the Electricity Supply Act of 1994. LUCELEC was privatized in this act with the aim that outside sources would provide financial funding for renewable energy development and the act provided voluntary financial incentives for it. In 1999, the Government of Saint Lucia announced that exemptions for import and consumption taxes would be given to developers of renewable energy but no institutional or regulatory framework was created to enforce it.[2,16]

Over a decade later, the National Energy Policy of 2010 was established in order to create an enabling regulatory and institutional environment towards increasing the renewable energy share in the energy mix. It set a goal to achieve a 5 per cent share of renewable energy in the mix by 2013, a 15 per cent share by 2015 and a 30 per cent share by 2020. Due to its non-intermittent nature and large potential, the plan favoured the development of geothermal energy to satisfy the base-load demand of electricity, but recognized the importance of all types of renewable energy. It granted grid preference to any type of renewable energy that would be available over fossil fuels, on the condition that the energy stability would not be compromised.[16] As of 2022, the goals that were set in this plan have not been reached.

In 2017, the Government and LUCELEC published the forward-looking National Energy Transition Strategy. This outlined possible scenarios of what the country's energy sector could look like in 2025, ranging from a 0 per cent share of renewable energy to an over 75 per cent share of renewable energy. Each scenario was tested on grounds such as potential future incurred debt, operational costs and external shocks such as high oil prices. Considering the country's economic standing it was found that the optimal strategy would be to install 30 MW of solar power and 12 MW of wind power by 2025. It was also recognized that unless foreign capital is used for geothermal energy development, it is not feasible for domestic investment despite the fact that it would be necessary to achieve the scenario of an over 75 per cent share of renewable energy.

In January 2020, LUCELEC made plans to set groundwork for a smart grid as well as to work towards the installation of a 10 MW solar power system and a 12 MW wind farm. These projects have since been put on hold due to the COVID-19 pandemic.[5]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The main barriers to SHP development in Saint Lucia include, but are not limited to:

- The generally low baseflows of the main rivers, which are unable to support hydropower plants;
- Other renewable energy sources, particularly solar power and wind power, are given a higher priority in the Government's policies and development plans, and in public and private sector projects.[13]

The key enablers for SHP development in Saint Lucia are:

- The positive feasibility study of SHP on the Roseau River that has not been taken advantage of;
- Inclusion of hydropower would lessen the country's over 90 per cent reliance on diesel and could help reach the set renewable energy goals.

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Saint Vincent and the Grenadines

Davy Rutajoga, International Center on Small Hydro Power (ICSHP)

KEY FACTS

Population	110,947 (2020)[1]
Area	389 km^2 [2]
Topography	The country consists of the main island, Saint Vincent, and a chain of 32 smaller islands, the Grenadines. Saint Vincent is a mountainous, volcanic island, located north of Trinidad and Tobago. It borders the Caribbean Sea in the west and the Atlantic Ocean in the east. The highest point is Soufriere, an active volcano with an altitude of 1,234 metres. Steep slopes and rugged landscapes comprise the remaining territory of Saint Vincent Mount Tobai, on Union Island, is the highest point in the Grenadines, with an altitude of 308 metres. The topography of the Grenadines is characterized by beaches and shallow bays.[3]
Climate	The climate of Saint Vincent and the Grenadines is tropical, characterized by increased humidity and uniform temperatures throughout the year. The average annual temperatures are estimated at 27 °C. September is the hottest month, with temperatures reaching an average of 29 °C. February is considered the coldest and windiest month. Winds in February reach on average 23 km/h and the average temperature is 25 °C.[4]
Climate Change	Saint Vincent and the Grenadines is affected by extreme climatic events associated with climate change, particularly, due to the country's location within the Atlantic hurricane belt. Some of these are intense hurricanes, such as the Hurricanes Ivan and Thomas of 2004 and 2010, respectively. The country is also experiencing warmer days and nights, unpredictable and reduced rainfall, droughts, floods, landslides, coral bleaching with rising ocean temperatures and coastal erosion.[5] The mean annual temperature is predicted to keep increasing at an average rate of 0.15 °C per decade. Rainfall is predicted to decrease, with negative median values of between 15 per cent and 22 per cent annually by the 2090s.[6]
Rain Pattern	The annual precipitation in Saint Vincent and the Grenadines is estimated to be between 1,500 mm and 6,000 mm.[7] Precipitation has seen a decline of approximately 8.2 mm per month per decade since 1960.[8] Rainfall is an important source of freshwater for the Grenadines and this decline is likely to affect water resources in the region.
Hydrology	There are no navigable rivers in Saint Vincent and the Grenadines, most of them being short and straight. The Colonaire is the longest river in the country. Other important rivers are the Buccament, Cumberland and Warrowarrow.[9] River defences were planned to be constructed on the Colonaire, Buccament, Cumberland and Warrowarrow by the Government of Saint Vincent and the Grenadines in collaboration with the Canada Caribbean Resilience Facility (CRF) as part of the Disaster Vulnerability Reduction Project (DVRP).[10]

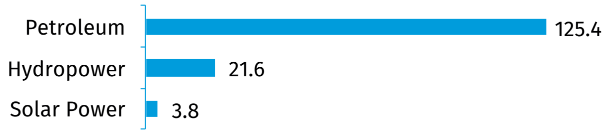
ELECTRICITY SECTOR OVERVIEW

The main sources of electricity in Saint Vincent and the Grenadines are petroleum and hydropower. The country is heavily reliant on imported petroleum, which accounted for approximately 83 per cent of the 150.8 GWh of electricity generated in the country in 2020. Hydropower accounted for less than 15 per cent and solar power accounted for less than 3 per cent of the generated electricity (Figure 1).[11] The installed capacity in the country in 2020 was 54 MW, with over 85 per cent from petroleum, over 11 per cent from hydropower and over 3 per cent from solar power (Figure 2).[11] The electricity in Saint Vincent and the Grenadines' islands of Bequia, Canouan, Mayreau and Union is generated, transmitted and distributed by Saint Vincent Electricity Services Ltd (VINLEC), which owns the monopoly in the region. Electricity on Mustique Island is produced by Mustique Company Ltd. Total access to electricity is estimated at 100 per cent.[11,12]

Figure 1. **Annual Electricity Generation by Source in Saint Vincent and the Grenadines in 2020 (GWh)**

Source: Statistical Office[11]

Figure 2. **Installed Capacity by Source in Saint Vincent and the Grenadines (MW)**



Source: Statistical Office[11]

The electricity in Saint Vincent and the Grenadines is regulated by VINLEC and the Cabinet of the Government of Saint Vincent and the Grenadines. VINLEC uses networks spanning over 563 kilometres to provide electricity to customers. It became a fully state-owned enterprise in 1985 after being incorporated in 1961 and selling an initial 49 per cent of its shares to the Government in 1971.[13]

In order to assist in formulating and implementing policies related to energy as well as coordinating specific activities related to renewable energy and energy efficiency initiatives, the Government of Saint Vincent and the Grenadines created the Energy Unit.[14]

The average electricity tariffs for the four main groups of consumers are listed in Table 1. According to VINLEC, a value-added tax (VAT) of 16 per cent is applicable to domestic customers who consume more than 150 kWh. This tax is also paid by all commercial and industrial customers.[15]

Table 1. **Average Electricity Tariffs in Saint Vincent and the Grenadines**

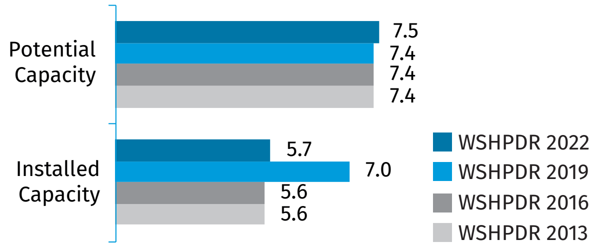
Type of consumer	*Average electricity tariff (USD/kWh)*
Residential	0.19
Commercial	0.20
Industrial	0.16
Street lighting	0.21

Source: ETI[16]

SMALL HYDROPOWER SECTOR OVERVIEW

The definition used by the country for small hydropower (SHP) is up to 10 MW. The installed capacity of SHP in Saint Vincent and the Grenadines is estimated at 5.7 MW and comes from three plants: the South Rivers, Richmond and Cumberland hydropower plants.[12] However, their capacity is not available at full scale year-round, with the available capacity decreasing to approximately 2 MW during the dry season, which creates the need to use diesel plants for back-up.[17] Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, the SHP installed capacity decreased based on more accurate data (Figure 3). The total SHP potential is estimated to be 7.5 MW.[12]

Figure 3. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in Saint Vincent and the Grenadines (MW)**



Source: CCREEE,[12] *WSHPDR 2013*,[18] *WSHPDR 2016*,[19] *WSHPDR 2019*[20]

Table 2. **List of Operational Small Hydropower Plants in Saint Vincent and the Grenadines**

Name	*Installed capacity (MW)*	*Plant type*	*Operator*	*Launch year*
Cumberland	3.65	Run-of-river	VINLEC	1987
Richmond	1.10	Run-of-river	VINLEC	1962
South Rivers	0.96	Run-of-river	VINLEC	1952

Source: VINLEC[21]

A study for the rehabilitation of the Richmond plant and the expansion of South Rivers plant was conducted in 2009. Due to favourable findings, VINLEC was prompted to undertake modernization and refurbishment projects at both plants. The first such initiative commenced in 2013 and the refurbishment works at the Richmond and South Rivers plants were completed in 2016 and 2018, respectively.[21] VINLEC also considered developing another power plant of 1.2 MW downstream South Rivers, on the Colonarie, but no updates on progress are currently available.

RENEWABLE ENERGY POLICY

The cost of energy in Saint Vincent and the Grenadines is relatively high. However, there is significant potential for the adoption and implementation of renewable energy. In order to address sustainability issues, the Government established the National Energy Plan (NEP) in 2009. In 2010, an additional document, the National Energy Action Plan (NEAP), provided more accurate details with regards to the initiatives both the public and the private sector will undertake to promote the dissemination of renewable energy projects in the country.[22]

While the National Energy Action Plan (NEAP) specified a diverse variety of measures for implementation and even designed short- and long-term targets, it has not been successful in achieving the set target of 60 per cent of electricity output produced through renewable energy by 2020.[11]

Although the country's potential is high, more financial and construction policies to motivate and accommodate investors are needed.

In addition to these policies, the country has also implemented feed-in tariffs (FITs), tax reductions and exemptions for the usage of renewable energy and green public procurement.

VINLEC has also undertaken multiple studies to evaluate the feasibility of investing in renewable energy. Some of the projects that the company is considering or recently completed in collaboration with the Government of Saint Vincent and the Grenadines are outlined below:

- Ribishi Point was identified as a suitable site for the development of wind power after a 2005 study conducted by VINLEC, however, the project stalled due to the proximity to the new airport and scaling down of the project is currently being explored; other locations, including some of the small Grenadines islands, are also being considered;
- The installation of solar panels on a car park canopy and the roofs of the transformers and back-up generator sheds at the Cane Hall Engineering Complex for a total capacity of 30 kW;
- A 370 kW solar PV plant installation project was commissioned at the Lowmans Bay Power Station in 2014 and is operational;
- A joint project with Emera Caribbean Inc. and Reykjavik Geothermal to develop the geothermal potential of the island; however, the project has been challenged by the lack of sufficient permeability of the resource tapped by the wells drilled;
- Generating electricity through the recovery of heat from waste is another measure that the Government of Saint Vincent is considering.[12,17,23,24,25]

The Regional Disaster Vulnerability Reduction Project is a USD 23 million project conceived in 2011 and aiming, among other things, to strengthen river embankments in Saint Vincent and the Grenadines. As part of this project, coastal areas and infrastructure are to be protected from climate change-related damage, thus ensuring the safety of hydropower plants. The final phase of the implementation of this project, set for December 2020, was hindered by the travel restrictions imposed to curb the spread of COVID-19.[26]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

SHP plants are regulated by some of the same legislation as larger hydropower plants. The main legislation and regulation documents in Saint Vincent and the Grenadines concerning hydropower are:

- The Electricity Supply Act (1973);
- Hydroelectric Ordinance No. 24 (1951).

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

There are numerous barriers to SHP development Saint Vincent and the Grenadines, including:

- No specific plan on SHP development has been defined;
- Despite the attempts to encourage investment in renewable energy, the market is still heavily reliant on fossil fuels for electricity production;
- VINLEC's monopoly may prevent smaller private companies from effectively developing and implementing renewable energy projects at profitable rates;
- Limited potential for SHP development, particularly on the smaller islands;
- Seasonal rainfall variability affects SHP as hydropower availability can decrease by 50 per cent or more during the dry season;
- SHP is no longer a priority for the Government, with most investment being focused on the development of solar and geothermal power.[27]

The factors that favour further SHP development in the country include:

- The Government has been actively promoting renewable energy solutions and has implemented initiatives to raise awareness of the efforts made by the country to embrace renewable energy and the potential for further investment;
- The Government has been increasingly promoting small-scale sustainable energy projects as well as the introduction of electric vehicles;
- Availability of incentives in the form of FITs, tax reductions and exemptions for the usage of renewable energy;
- Availability of financial and capacity building support from international institutions, such as the Global Environment Facility (GEF), World Bank, International Renewable Energy Association (IRENA), etc.[12,28,29]

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Contributing organizations

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Punjab Power Development Board
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