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INTERNATIONAL CENTER
ON SMALL HYDROPOWER

World Small Hydropower Development Report 2022

Central America

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Table of Content

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Central America

Countries: Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama

INTRODUCTION TO THE REGION

The electricity sectors of countries in Central America are marked by a relatively high degree of diversification, high electricity access and significant involvement of private companies. Fossil fuels are the leading source of electricity generation in Guatemala, Mexico and Nicaragua. In other countries in the region fossil fuels generally play a supporting role, with thermal power capacities held in reserve to supplement variable generation from renewable energy sources (RES). For example, in Belize, thermal power from fossil fuels accounted for just 9 per cent of annual generation in 2020. Nearly all major RES are well-established in the region, including hydropower, solar power, wind power and bioenergy. This also includes geothermal power, which is widely used across Central America and plays a particularly important role in the electricity mix of El Salvador and Nicaragua.

Central America is well-supplied with hydropower resources, and hydropower is the leading RES in the region by installed capacity. Mexico accounts for the largest share of regional hydropower capacity, while Belize and Costa Rica have the highest proportion of their installed capacity provided by hydropower. Although nearly all countries in the region rely on hydropower to a significant extent, the interannual and seasonal variability in generation from hydropower in the region requires the maintenance of significant reserve capacities provided by other energy sources.

Private companies play a major role in the production of electricity in the region. During the 1990s, most countries in the region underwent a period of liberalization and privatization in the energy sector, with state-owned energy companies including electricity producers, providers and companies in the oil and gas sector undergoing unbundling and partial or full privatization. The process of electricity sector privatization has continued through the first two decades of the 21st century but has generated increasing opposition, particularly in Mexico. Among the countries in the region, the electricity sectors of Honduras and Guatemala are the most fully privatized, with private companies operating 80 per cent and 86 per cent of these two countries' respective electricity capacities. In other countries, the share of installed capacity operated by private companies is in the 20–50 per cent range.

The degree of interconnectivity in the region is very high, with El Salvador, Costa Rica, Guatemala, Honduras Nicaragua and Panama all connected to the Central American Electric Interconnection System (SIEPAC). The Mexico-Belize interconnection is likewise important and provides Belize with roughly a third of its electricity supply. Mexico has additional interconnections with Guatemala as well as with the United States of America on its northern border, while Panama shares interconnections with its southern neighbour Columbia.

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

Table 1. **Overview of Central America**

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)*
Belize	0.4	93	88	132	433	55	242
Costa Rica	5	99	N/A	3,566	11,313	2,343	7,827
El Salvador	7	98	95	2,360	5,388	574	1,985
Guatemala	17	92	N/A	3,993	12,224	1,560	4,381
Honduras	10	85	71	2,830	10,888	849	3,765
Mexico	126	100	100	87,894	317,820	12,614	23,602
Nicaragua	7	88	74	1,620	3,797	157	575
Panama	4	96	88	4,128	10,887	1,810	7,226
Total	-	-	-	**106,523**	-	**19,961**	-

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

There is no universally-accepted definition of small hydropower (SHP) in Central America. Honduras defines SHP as hydropower plants with an installed capacity of up to 30 MW. El Salvador and Guatemala adhere to the up to 5 MW definition, in line with the definition proposed by the Latin American Energy Organization (OLADE), while Nicaragua uses the up to 10 MW definition. No official definition of SHP exists in Belize, Costa Rica, Mexico or Panama, although Panama provides incentives for hydropower plants of up to 20 MW without classifying such plants as SHP, and Mexico uses the up to 30 MW definition for the purpose of incentivization.

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

Table 2. **Small Hydropower Capacities by Country in Central America (MW)**

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed capacity (≤10 MW)*	*Potential capacity (≤10 MW)*
Belize	N/A	N/A	N/A	10.3	21.7
Costa Rica	N/A	N/A	N/A	126.5	126.5*
El Salvador	Up to 5 MW	21.7	N/A	21.7	119.6
Guatemala	Up to 5 MW	123.0	204.9	123.0**	204.9**
Honduras	Up to 30 MW	288.6	N/A	148.0	385.0
Mexico	N/A	699.3***	N/A	N/A	N/A
Nicaragua	Up to 10 MW	26.6	104.7	26.6	104.7
Panama	N/A	N/A	N/A	147.2	263.5
Total	-	-	-	**603.3**	**1,225.9**

Source: WSHPDR 2022[1]

Note: *Based on installed capacity. **Based on the local definition of SHP. ***Based on the up to 30 MW definition of SHP.

The total installed capacity of SHP up to 10 MW in Central America is 603.3 MW, while estimated potential capacity is 1,225.9 MW. Relative to the World Small Hydropower Development Report (WSHPDR) 2019, the installed capacity has increased 15 per cent due to ongoing SHP development in several countries in the region, including Guatemala, Honduras, Nicaragua and

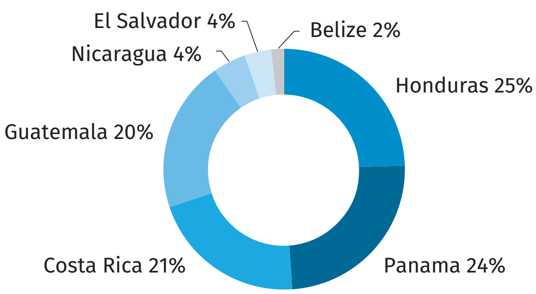
Panama. Meanwhile, the estimate of potential capacity has increased by approximately 2 per cent, mainly as a result of more recent data on the estimated potential SHP capacity of Nicaragua.

Mexico is the regional leader in SHP capacity based on the SHP definition of up to 30 MW, but even under this definition SHP accounts for only a small share of the country's total hydropower capacity. By contrast, SHP accounts for 17 per cent of all hydropower capacity in Nicaragua, 17 per cent in Honduras and nearly 19 per cent in Belize. Guatemala, Honduras, Nicaragua and Panama have all seen significant increases in total installed SHP capacity in recent years. Factors that have contributed to SHP development in these countries include state-supported incentive schemes as well as funding provided by international development programmes. In Belize, Costa Rica, El Salvador and Mexico, little recent SHP development has taken place.

Challenges faced by the SHP sector in the region require a comprehensive response. In particular, climate change is emerging as a major barrier to SHP development, and needs to be addressed through appropriate planning and adaptation measures, particularly in the case of prolonged drought. Climate change response in the region requires a more effective model of public-private-community collaboration, including the introduction of integrated watershed management that would provide a platform for local communities to fully participate in the decision-making and profit-sharing aspects of SHP construction and operation.

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

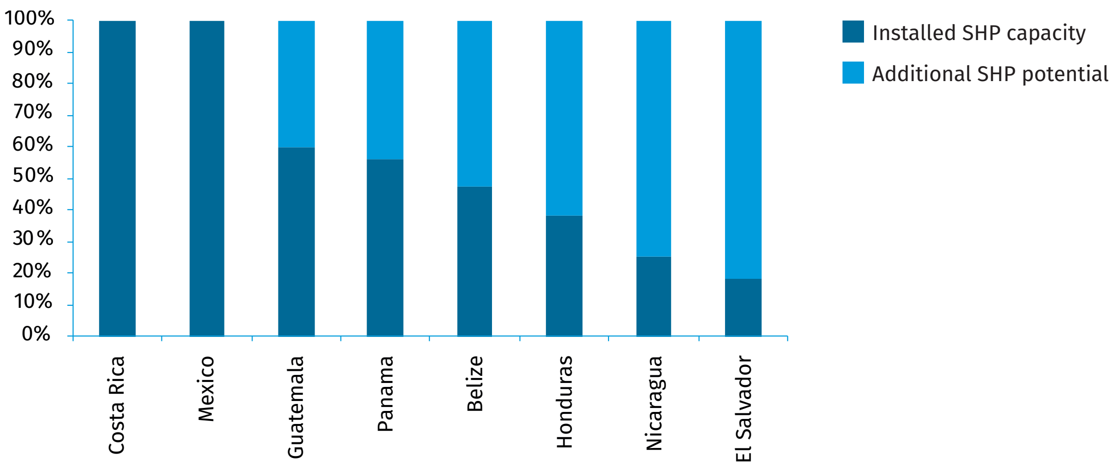
Figure 1. **Share of Regional Installed Capacity of Small Hydropower up to 10 MW by Country in Central America (%)**



Source: WSHPDR 2022[1]

Note: Mexico not included due to lack of data on SHP up to 10 MW.

Figure 2. **Utilized Small Hydropower Potential by Country in Central America (%)**



Source: WSHPDR 2022[1]

Note: For SHP up to 10 MW except in the case of Mexico, where the up to 30 MW definition is used, and Guatemala, where the local definition is used. For Costa Rica and Mexico, all SHP potential is assumed to be utilized due to a lack of reliable estimates of potential capacity.

The installed capacity of SHP up to 10 MW in **Belize** is 10.3 MW, provided by two SHP plants, and has not changed since the commissioning of the second plant in 2005. The potential capacity is estimated at 21.7 MW, indicating that approximately 47 per cent has been developed. The most recent study of SHP potential was carried out in 2006. Since then, no additional activity related to the SHP sector has taken place.

In **Costa Rica**, the installed capacity of SHP up to 10 MW is 126.5 MW, while the estimate of potential capacity is 7,373.5 MW, indicating that approximately 2 per cent has been developed. No new SHP construction has taken place in the country in recent years, although the assessed installed capacity has been revised upwards due to access to better data on existing SHP plants. The estimate of potential SHP capacity in the country is provided on the basis of a 2017 study assessing worldwide hydropower potential.

In **El Salvador**, there are 17 operational SHP plants with a total installed capacity of 21.7 MW, in addition to two plants with a capacity of 0.63 MW that are likely decommissioned or in need of extensive repairs. All existing SHP plants in the country have an installed capacity under 5 MW, and there are no plants in the 5–10 MW capacity range. The potential capacity for SHP up to 10 MW has been estimated at 119.6 MW, of which 18 per cent has been developed. There are two ongoing SHP projects on the San Simon River.

There are 65 operational SHP plants of up to 5 MW in **Guatemala** with a total installed capacity of 123 MW. An additional 33 plants with a total capacity of 80 MW are registered with the Government but are not operational, and one SHP plant with a capacity of 1.9 MW is pending registration. On the basis of these capacities, total potential SHP capacity of up to 5 MW in Guatemala is estimated at 204.9 MW, of which 60 per cent has reached operational status. The undeveloped SHP potential of the country is likely to be higher but no reliable estimate is available.

In **Honduras**, the installed capacity of SHP of up to 30 MW is 288.6 MW provided by 45 plants, of which 37 are plants of up to 10 MW and with a combined capacity of 148 MW. Potential capacity for SHP up to 10 MW is estimated at 385 MW, indicating that 38 per cent has been developed. The installed SHP capacity of the country has been growing steadily over the last decade due to the construction of new plants, but no data on ongoing SHP projects are available.

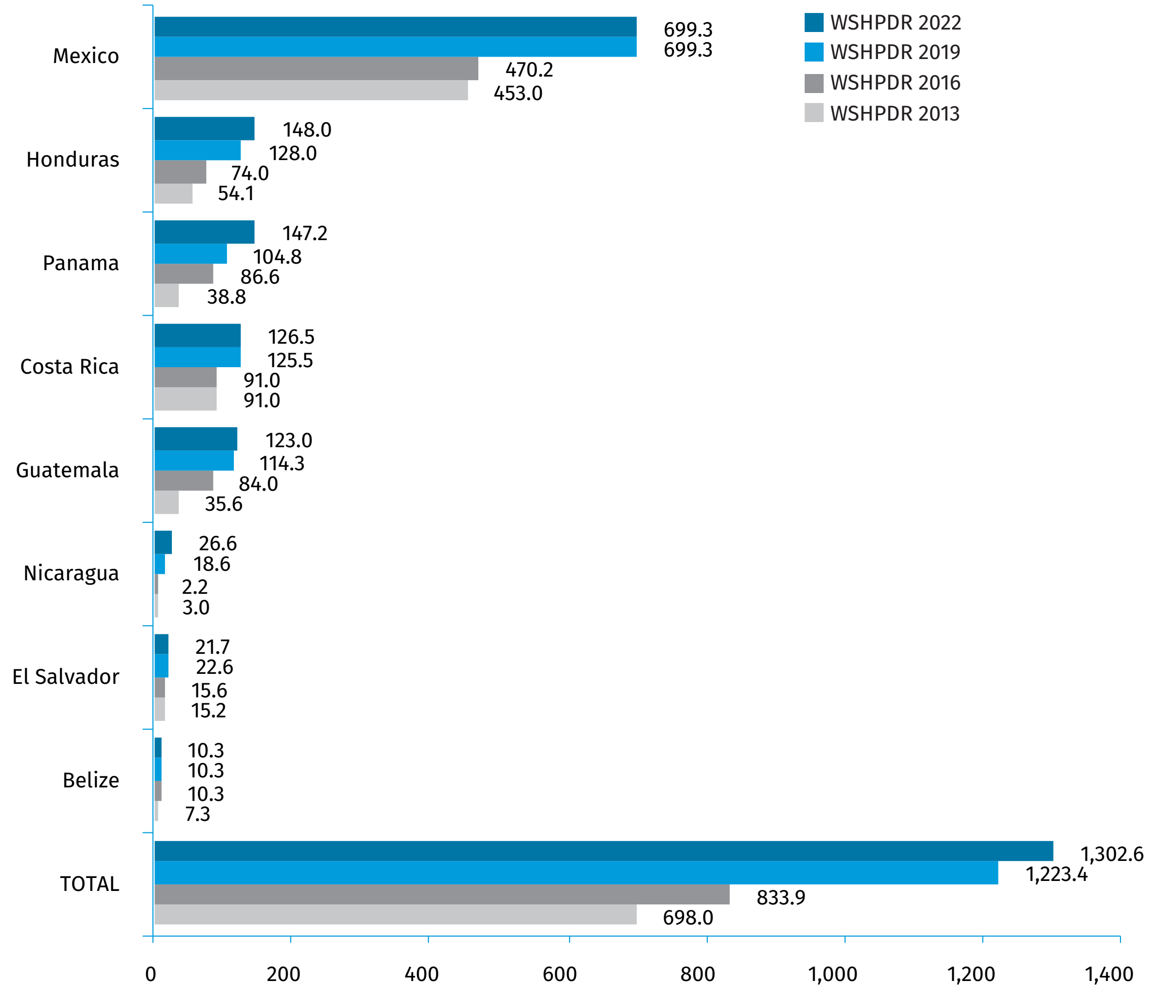
The installed capacity of SHP up to 30 MW in **Mexico** is 699.3 MW, provided by 69 plants. There is no reliable estimate of potential SHP capacity in the country. A large number of studies of SHP potential have been carried out over the last few decades in different parts of the country, producing estimates that differed by a wide margin. At the high end, one study suggested the existence of over 3,000 potential micro-, mini- and small hydropower sites across the country. In addition to existing SHP plants, 41 SHP plants were under construction across the country as of 2021, with a combined planned capacity of 452.5 MW.

There are 17 operational SHP plants of up to 10 MW in **Nicaragua** with a total installed capacity of 26.6 MW. Based on an inventory of 20 potential SHP sites, potential capacity for SHP of up to 10 MW is estimated at 104.7 MW, indicating that 25 per cent has been developed. Three new SHP plants have been constructed in the country in recent years and several additional potential sites have been identified.

The installed capacity of SHP of up to 10 MW in **Panama** is 147.2 MW provided by 24 operational SHP plants, while potential capacity is estimated at 263.5 MW, indicating that 56 per cent has been developed. The installed SHP capacity of the country has expanded considerably over the last few years. There were 9 additional plants under construction as of 2021 and 13 other potential SHP sites have been identified.

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 from *WSHPDR 2013* to *WSHPDR 2022* by Country in Central America (MW)**



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

Note: For SHP up to 10 MW except in the case of Mexico, where the up to 30 MW definition is used, and Guatemala, where the local definition is used.

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 on exposes SHP infrastructure to damage as well as decreases SHP plant load factors due to persistent drought.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

In **Belize**, there are no outstanding plans for any further expansions to existing SHP capacity and no incentives or funding are provided for SHP development. This lack of interest is partially informed by the increasing volatility of hydropower generation as a result of rainfall variability induced by climate change, as well as by observed negative impacts of hydropower on the environment. However, given the positive impact of international funding on the development of other RES in the country, similar support could be attracted to develop the country's remaining SHP potential.

Barriers to the development of SHP in **Costa Rica** include environmental restrictions, seasonality of river flow, competitive advantages of solar power and wind power projects, and low electricity demand. The key enabling factor for future development is the country's massive estimated SHP potential. Additionally, Costa Rica possesses considerable technical capacity in the SHP sector and a well-established framework for the development of RES projects.

SHP development in **El Salvador** is hampered by outdated hydrological data and assessments of SHP potential, as well as insufficient financing, competition from other RES due to relatively high development costs, uncertainties in the licensing process and social opposition. At the same time, the estimated SHP potential of the country is considerable and well-documented, although more up-to-date studies are needed.

In **Guatemala**, SHP development has faced opposition for social and environmental reasons, forcing the Government to develop a special consultation framework to address these concerns. Even when SHP development is not opposed by local communities, there are often problems with acquiring funding for SHP projects, particularly in light of the costs of construction and transmission in remote areas. On the other hand, SHP development in the country is facilitated by supportive government policy and by an established system for licensing and regulating SHP projects.

Barriers to SHP development in **Honduras** include issues with road access and transmission of electricity, as well as greater interest on the part of private investors in large power plants. Enablers include the highly liberalized electricity market that simplifies entry for new companies, high demand for electricity access in the countryside and abundant undeveloped SHP potential.

SHP development in **Mexico** faces a wide range of regulatory, financial, technical and political obstacles, including a lack of feed-in tariffs (FITs), rising cost of transmission, a difficult licensing process and a negative public perception of SHP. Lack of accurate nationwide data on SHP potential is another major barrier to development, although detailed partial inventories of potential sites have been developed. Despite a lack of rigorous data, the country's SHP potential is believed to be very considerable and could be more fully realized with the aid of existing incentives such as tax breaks. Additionally, the SHP sector in Mexico is well-positioned to take advantage of rising electricity demand and attractive regional electricity export prices. Finally, Mexico is a major hydropower producer and SHP developers can lean on considerable local technical expertise and construction capacities.

The main barriers to SHP development in **Nicaragua** are financial in nature and include the high upfront cost of projects, the short duration of power purchase agreements, which discourages investors, as well as subsidies for thermal power plants, which put SHP at a competitive disadvantage. Additionally, there is insufficient local technical capacity in the SHP sector. However, the country has few restrictions on foreign direct investment in the energy sector and government policy is strongly supportive of RES development, providing a range of fiscal incentives. The need to extend electricity access to certain rural areas is an additional enabler of SHP development in Nicaragua.

The most important barrier to SHP development in **Panama** is the lack of interest from private finance, meaning that SHP projects, particularly those initiated in rural communities, are dependent on state financing. At the same time, the established legal framework and system of incentives are highly supportive of SHP development, and the country has considerable experience in hydropower as well as significant untapped SHP potential. Furthermore, several ongoing SHP projects in the country have stalled and may be looking to solicit additional investments.

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Belize

Areli Sutherland and Geon Hanson, Energy Unit of Belize

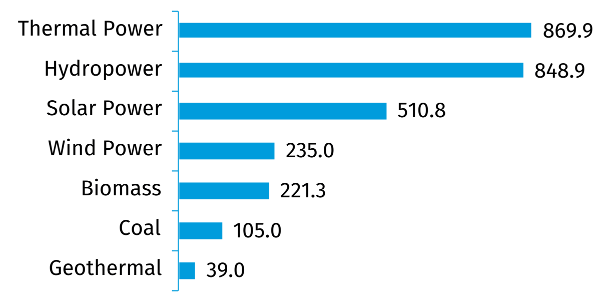
KEY FACTS

Population	397,621 (2020)[1]
Area	22,965 km^2 [2]
Topography	The topography of Belize consists of lowlands and swamps along its northern coast and the Maya Mountains in the southern part of the country. The highest point in Belize is Doyle's Delight at 1,124 metres above sea level.[2]
Climate	The climate of Belize is classified as subtropical. It is characterized by a dry season lasting from late February to May and a wet season lasting from June to November. Average temperatures in Belize City range from 23 °C in December to 29 °C in July.[2]
Climate Change	Belize is considered one of the countries at greatest risk from climate change, ranking third among small countries in susceptibility to natural disasters and fifth in climate change risk. This vulnerability is most significant with regard to hurricane damage from wind, storm surges and other flooding due to the country's coastal position and low elevation of large parts of the country. Projected changes in climate include an increase in temperatures of 2–4 °C by 2100, a 6–8 per cent increase in the length of the dry season with a corresponding shortening of the rainy season and a 20 per cent increase in the intensity of heavy rainfall events.[3,4]
Rain Pattern	The rainy season lasts from June to November, and the dry season is from February to May. Average precipitation depends on the region. In the south, annual rainfall can reach over 4,000 mm, while in the north it can be less than 1,800 mm.[2]
Hydrology	Belize has 18 major rivers in addition to many smaller perennial streams. The Belize River is the largest, running from the Maya Mountains and its tributaries in Guatemala to the Caribbean Sea for a total length of 290 kilometres and draining approximately a quarter of the country's area. Other major rivers include the Sibun River in the south and the New River in the north.[5]

ELECTRICITY SECTOR OVERVIEW

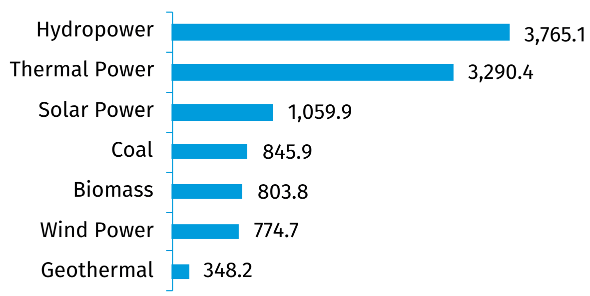
The total installed capacity of existing power plants in Belize was approximately 131.7 MW in 2020. Thermal power from fossil fuels providing 55.3 MW (42 per cent) of the total, hydropower provided 54.5 MW (41 per cent), biomass provided 21.5 MW (16 per cent) and utility-scale solar power provided an estimated 0.5 MW (less than 1 per cent) (Figure 1). In addition, approximately 3 MW of distributed solar power generation is estimated to exist in the country, but data on specific installations is not available.[6,7,8]

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



Source: Persson,[6] Energy Unit[7,8]

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

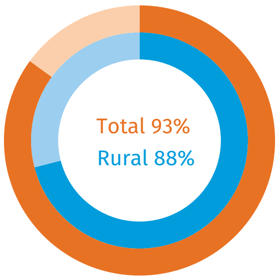


Source: Energy Unit[7,10]

Electricity generation in Belize amounted to 433.2 GWh in 2020, with the share of renewable energy sources (RES) including hydropower reaching 90 per cent. Hydropower provided 242.1 GWh (56 per cent) of the total generation, biomass provided 149.5 GWh (35 per cent), thermal power from fossil fuels provided 41.0 GWh (9 per cent) and solar power provided 0.6 GWh (less than 1 per cent) (Figure 2). The relative contribution of the different sources to the electricity supply changed dramatically from 2019, when hydropower provided only 74.7 GWh, while thermal power from fossil fuels provided 137.2 GWh. Major fluctuations in hydropower generation occurred throughout 2018-2020 due to changing hydrological conditions, requiring increasing imports from Mexico as well as generation from thermal power during certain periods. Imports of electricity from Mexico in 2020 amounted to 270.2 GWh, decreasing from 383.7 GWh in 2019.[7,9,10]

Consumption of electricity in Belize in 2020 was 539.3 GWh, representing a decline of over 8 per cent from the 2019 total consumption of 588.4 GWh. Consumption was dominated by the residential and commercial sectors at 245.3 GWh and 249.8 GWh, respectively, with industry and street lighting accounting for the remaining 44.1 GWh.[7,9,10] Overall electricity access in the country was estimated at 93 per cent in 2019, without taking into account consumers connected to off-grid generation sources.[11] Such off-grid systems are known to exist but have not yet been accurately documented. Rural access to electricity in 2019 was estimated at 88 per cent (Figure 3).[12]

Figure 3. **Electrification Rate in Belize in 2019 (%)**



Source: World Bank[12]

As the national utility, Belize Electricity Limited (BEL) is one of the largest single stakeholders in the energy sector of Belize and the only entity in the country with the legal mandate for transmission and distribution of electricity. In addition to owning and operating most grid infrastructure, BEL is a major power producer, operating the Westlake Sub Gas Turbine power plant, the Caye Caulker diesel power and mobile generators with a combined installed capacity of 32.5 MW.[6,7] As of 2020, generation contractors supplying electricity to the BEL national grid system included Santander Sugar Energy Limited (SSEL) and Belize Cogeneration Energy Ltd. (BELCOGEN) using bagasse, Blair Athol Power Company Ltd. (BAPCOL) using heavy fuel oil and Hydro Maya Limited. These entities are regulated by the Public Utilities Commission (PUC). Other independent power producers include the Belize Electric Company Limited (BECOL), which operates hydropower plants, as well as a number of small-self generators like the Farmers Light Plant Corporation in the Spanish Lookout Mennonite Community and the University of Belize solar power plant, which do not currently fall under the PUC regulatory umbrella and are regulated by other national government bodies.[8]

Since its commissioning in 2001, the PUC has been the regulatory body responsible for the electricity, water and telecommunication sectors in Belize. The PUC aims to hold the utilities to a high standard by providing high-quality services at a reasonable cost to consumers. The Directorate of Electricity within the PUC was formed by the Government in order to focus on the regulation of all entities that are licensed under the Belize Electricity Act (2000). Major activities undertaken by the Directorate include: annual review of tariffs and full tariff review every four years for the BEL; licence compliance audits; and reliability and efficiency review for licences held by BEL as well as those issued to field technicians hired by BEL. The purpose of license review is to ensure service quality and consistency within the relatively small Belize energy sector, as a supply deficit from even one power provider could have serious ramifications for electricity access in the country.[13]

Another key stakeholder in the electricity sector is the Ministry of Public Utilities, Energy and Logistics, which oversees the Energy Unit of Belize. The role of the Energy Unit comprises the development of policies, strategic direction and plans for the national energy sector as well as oversight of all matters related to energy and the country's public utilities.

All major load centres across Belize are connected to BEL's national grid system. BEL operates a transmission line backbone consisting of 115 kV and 69 kV lines, running in a north-south direction across the country and interconnected with the Mexican national electricity grid in the north. The 115 kV transmission line covers the entire northern and western zone of Belize, while the southern half of the country is fed via the 69 kV transmission line and 34.5 kV circuits feed the 115 kV backbone to transport electricity to Corozal, Orange Walk and San Pedro. Currently, Caye Caulker and the Spanish Lookout community remain as isolated load centres supplied with electricity by off-grid thermal power plants running on diesel and crude oil.[7]

Table 1. **Electricity Tariffs in Belize**

Category	*Tariff (USD/kWh)*	*Demand charge (USD)*	*Minimum/service charge (USD)*
Social	0.110	N/A	2.50
Residential	0.165–0.215	N/A	5.00
Commercial 1	0.165–0.215	N/A	5.00
Commercial 2	0.190–0.205	N/A	75.00
Industrial 1	0.150	17.91	125.0
Industrial 2	0.130	11.50	125.0
Street lights	0.225	N/A	N/A

Source: BEL[14]

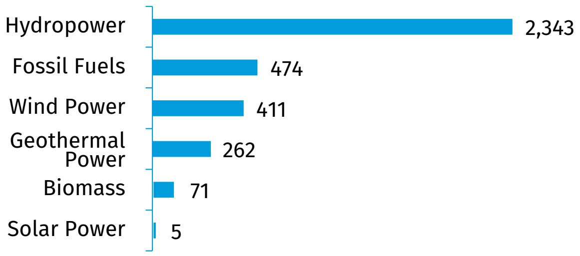
Note: Tariffs valid for the period July 2021–June 2024.

Electricity tariffs for final consumers include a minimum charge and a block charge based on consumption volume for social, residential and commercial consumers and charges based on demand and consumption for industrial consumers. Rates valid for the period from 1 July 2021 to 30 June 2024 are displayed in Table 1.

SMALL HYDROPOWER SECTOR OVERVIEW

There is no national definition of small hydropower (SHP) in Belize. Under the up to 10 MW definition of SHP, there were just two SHP plants in the country as of 2020, with a total installed capacity of 10.3 MW.[7] Additional undeveloped potential capacity is estimated at 11.4 MW, indicating that 48 per cent of the country's SHP potential has been developed so far.[15] Neither installed nor estimated potential capacity have changed relative to the World Small Hydropower Development Report (WSHPDR) 2019 (Figure 4).[16] Existing SHP plants in Belize are listed in Table 2.

Figure 4. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in Belize (MW)**



Source: Energy Unit,[7] PÖYRY,[15] WSHPDR 2019,[16] WSHPDR 2013,[17] WSHPDR 2016[18]

Table 2. **List of Existing Small Hydropower Plants in Belize**

Name	*Location*	*Capacity (MW)*	*Generation in 2019 (GWh)*	*Generation in 2020 (GWh)*	*Plant type*	*Operator*	*Launch year*
Chalillo	Maya Mountains, Western Belize	7.0	6.86	29.03	Reservoir	BECOL	2005
Hydro Maya	Southern Belize	3.3	9.96	13.48	Run-of-river	Hydro Maya Ltd.	2003

Source: Energy Unit[7,9,10]

The most recent study of the hydropower potential in Belize was carried out in 2006. The study identified a number of promising sites for hydropower development, including sites on the Macal River and its tributaries with potential capacities of between 2.0 MW and 8.4 MW, a 1 MW site on the Privassion River and potential low-head sites along the Mopan River with a total maximum potential capacity of 15–20 MW.[15] Additional potential hydropower sites have been identified near Chiquibul as well as on the Monkey River and South Stann Creek, but no reliable estimates of potential capacity are available.[16]

RENEWABLE ENERGY POLICY

Renewable energy development targets are outlined in the Energy Policy of Belize as well as in the Nationally Determined Contribution (NDC) under the United Nations Framework Convention on Climate Change (UNFCCC), last updated in 2021. The NDC established the goal of cutting 44 kilotons of CO_2 emissions annually and the target of a 75 per cent share of RES in the national electricity supply by 2030. These targets are to be met in part through an expansion of RES capacities, including an additional 19 MW of installed hydropower capacity.[4]

In 2019, a Consolidated Project Plan (CPP) was developed and published as a collaboration between national stakeholders and the Caribbean Center for Renewable Energy and Energy Efficiency (CCREEE). The CPP provides a consolidated framework for streamlining policy targets and utility goals and incorporates RES targets established under the earlier versions of the NDC. The CPP represents a tool for further planning pertaining to both energy efficiency and renewable energy as well as for identifying opportunities within the electricity sector that offer significant economic, social and environmental benefits for the citizens of Belize.

Additional steps supporting the diversification of the energy mix of Belize and the development of hydropower in particular included the 2013 Request for Proposals (RFP) to secure adequate electricity generation or supply capacity to satisfy electricity demand in the country for the next 15 years at least cost, to be submitted through a competitive bidding process. The issued RFP targeted not only the addition of new generation capacities from RES, but also the gradual replacement of high-cost thermal generation with RES generation where possible.[19] However, no new SHP capacity was added under the 2013 RFP, and no new RFPs are being planned as of 2022.[8]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

The only in-country programme that could be considered as a financial mechanism available for SHP development is a loan initiative from the Development Finance Corporation (DFC) targeted towards homeowners and businesses for the promotion of RES in the private sector. The scope of the financing available through this scheme with regard to utility- or grid-scale plants is limited.[8]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

In both 2018 and 2019, Belize experienced an intensified dry season resulting in severe droughts, which damaged the agricultural sector and reduced the supply of electricity from hydropower as well as from biomass-fired power plants. These conditions necessitated a greater dependence on imports of electricity from Mexico, which directly corresponded to an increase in the cost of power for grid consumers in Belize.[20]

BECOL, in adjusting to the increasing volatility of hydropower generation, is developing plans to diversify its feed to the grid by adding utility-scale solar power systems to its generation mix. Generally, the effect of climate change on generation from RES is marked and will require careful planning to sustainably pursue further development.[8]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

In summary, while Belize possesses both operational SHP plants and potential for further SHP development, there are currently no defined plans in place to further develop the SHP sector, largely due to natural challenges and lack of incentives and investment.

Some barriers to SHP development in the country are:

- Increasing volatility of rainfall and hydropower potential due to climate change effects;
- Some negative environmental impacts have been observed, including elevated levels of metals in river fish, that are attributed to hydropower in general rather than specifically to SHP;
- No plans other than the NDC goals are currently in place to expand SHP;
- No financial incentives, allotted funds or large-scale investments are readily available for SHP projects.

Enablers for SHP development in Belize include:

- More than half of the identified SHP potential in the country is still undeveloped;
- The hydropower potential is recognized in the NDCs and other government policies;
- The hydropower and SHP technology is mature and already in use in the country;
- International funding and loans could be pursued to supply financial resources for SHP, as precedents exist for other RES.

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Costa Rica

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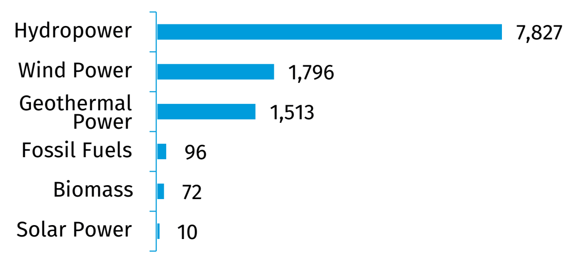
KEY FACTS

Population	5,111,238 (2020)[1]
Area	51,100 km^2 [1]
Topography	The topography is irregular, with valleys, mountain ranges and plains. Three main mountain ranges run in the longest direction, from north-west to south-east, descending towards the coastal plains and dividing the country into two slopes — the Pacific and the Caribbean. In the north-west, the Guanacaste and Tilarán Volcanic Mountain Ranges have the lowest peaks. In the centre of the country, the Central Volcanic Mountain Range forms the Central Valley. It is the most urbanized area in the country, where the capital city, San Jose, is located. The Talamanca Mountain Range lies in the south-east, with the highest peaks. Mount Chirripó is the highest mountain in Costa Rica with an elevation of 3,819 metres.[2]
Climate	Costa Rica lies within the tropical zone, between the Tropics of Cancer and Capricorn. The tropical climate is influenced by the topographic, oceanic, isthmus location and general atmospheric circulation factors. The average annual temperature is 25 °C. The country is divided into three general climate regions. The Tropical Caribbean Wet Region with monthly mean extreme temperatures between 22 °C and 31 °C. The Central Intermontane Region, with monthly mean extreme temperatures between 13 °C and 27 °C. The Tropical Pacific Region with monthly mean extreme temperatures between 23 °C and 33 °C.[3,4]
Climate Change	Climate change scenarios forecast increased rainfall south of the Caribbean and Pacific regions. Decreased rainfall is expected north of the Pacific and Central regions.[3,4]
Rain Pattern	Annual average accumulated rainfall is 3,297 mm. Different rain patterns occur in the Caribbean and the Pacific slopes. The Caribbean slope is wetter, without a defined dry season, with heavy rainfalls occurring in December and lower rainfalls occurring in February, March, September and October. Annual average accumulated rainfall in the Caribbean highlands reaches values as high as 8,000 mm. The Pacific slope is drier, with defined wet and dry seasons. The former extends between December and March; the latter extends between May and October. April and November are transitional periods. The Northern Pacific is the driest zone with annual average rainfall as low as 1,400 mm in the lowlands.[2]
Hydrology	The territory is divided into 34 main watersheds: 18 in the Caribbean slope and 16 in the Pacific slope. The largest is the Grande de Térraba watershed in the Southern Pacific, with an area of 5,085 km^2. Mean annual river flow in the territory is 70 litres per second (lps) per km^2 of watershed area. The Caribbean and Southern Pacific river flows are as high as 180 lps per km^2 of watershed area. The Grande de Térraba River has the highest mean annual flow, with 340 m^3 per second. The Northern Pacific river flows are lower than 30 lps per km^2 of watershed area.[2]

ELECTRICITY SECTOR OVERVIEW

Electricity generation in Costa Rica in 2019 reached 11,313 GWh, with 99 per cent coming from renewable energy sources, mainly hydropower (Figure 1). Seasonal variation of electricity consumption is minor, slightly higher in the dry season. Domestic electricity demand in 2019 was 11,334 GWh. Net imports within the Regional Electric Market (MER) with Central-American countries fulfilled 21 GWh for domestic electricity demand. The installed capacity in 2019 was 3,566 MW (Figure 2).[5]

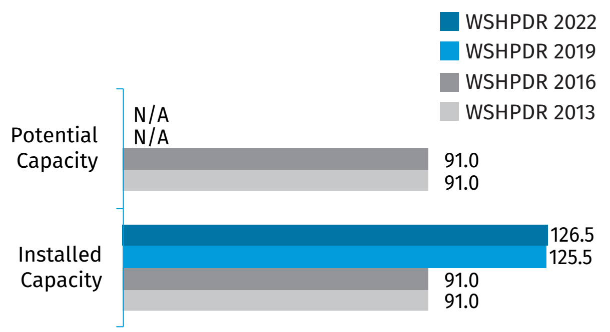
Figure 1. **Annual Electricity Generation by Source in Costa Rica in 2019 (GWh)**



Source: ICE[5]

The share of renewable energy sources in the National Electrical System (SEN) of Costa Rica is highly influenced by hydropower seasonality. During the rainy season, hydropower resources are plenty and SEN run-of-river hydropower plants spill surplus river flows. However, in the dry season hydropower resources are scarce, as a result, run-of-river production decreases significantly and hydropower generation depends on large-scale storage hydropower plants. Energy demand is then fulfilled by geothermal power or other renewable sources whose availability increases precisely in this season. Wind power and sugar cane bagasse biomass as well as endorsement from fossil fuel thermal power plants are required in a minor proportion.

Figure 2. **Installed Capacity by Source in Costa Rica in 2019 (MW)**



Source: ICE[5]

National electrification rate in 2019 was 99.4 per cent of total occupied dwellings. [6] Electricity demand grew by 1.9 per cent in 2019 compared to 2018.[5] The Energy Transition Index Report 2019 ranked the performance of the energy system of Costa Rica among the top 10 countries worldwide.[7] The public company, Costa Rica Electricity Institute (ICE), guarantees the electricity supply needed for the country's development, as mandated by Law 449.[8] ICE produces most of the electricity in the country, manages the transmission system and most of the distribution lines. Furthermore, the company is responsible for the planning and overall operation of the SEN. In 2019, ICE generated the biggest share of total electricity supply, accounting for almost 64 per cent. The share of public services distribution companies stood at 12 per cent. The private sector generation contributed 24 per cent.

Transmission lines extend widely, between the borders with Nicaragua and Panama and the Caribbean and Pacific coasts, totalling 1,725 km for 230 kV lines and 654 km for 138 kV lines. The Central American Electric Interconnection System (SIEPAC), which was completed in 2014, is the backbone of MER, which is operated by Ente Operador Regional (ORG).[9] In 2019, energy transactions within MER reached 3,074 GWh, the highest transaction volume since the establishment of MER.[10]

The main power production zone in the country is in the Northern Pacific, with hydropower plants located on rivers flowing towards the Caribbean, wind farms, geothermal fields, biomass and solar power plants.[11] The Central Valley is the main consumption zone. Distribution lines are managed by eight public services distribution companies, including ICE. [12] In 2017, an overload in the SIEPAC transmission line on the Panama side caused the most recent outage in Costa Rica. Before 2017, SEN had accomplished 10 years of service without outages.[13]

The long-term planning for the SEN is defined by ICE, in its Electric Generation Expansion Plans. For the 2018–2035 period, electricity demand is estimated to increase annually by 1.8–2.4 per cent. Capacity additions will be based entirely on renewable energy technologies.[12]

Electricity prices in Costa Rica are regulated, with no subsidies. The Public Services Regulatory Authority (ARESEP) defines methodologies for setting the tariffs. Prices differ according to the public services distribution company and the sector. The electricity prices in Costa Rica experience strong variations between the wet and dry season. The lowest annual average electricity price in 2020 was 0.09 USD/kWh for the commercial and services sector with consumption above 3,000 kWh. The highest annual average price was 0.27 USD/kWh for the industrial sector with consumption below 3,000 kWh.[14]

SMALL HYDROPOWER SECTOR OVERVIEW

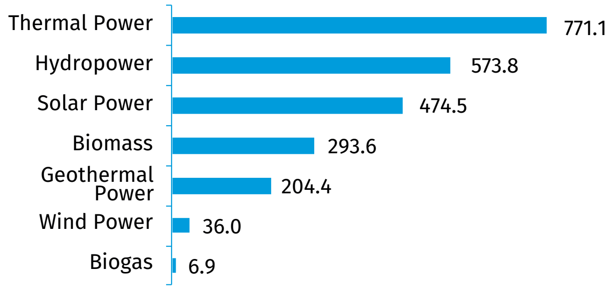
There is no official local definition for small hydropower (SHP) in Costa Rica. Law 7200 defines that the private sector and cooperative companies can produce autonomous energy with limited capacity power plants (LCP) defined as hydropower or non-conventional plants with capacity up to 20 MW.[9]

In 2020, there were 37 SHP plants (up to 10 MW) in operation in Costa Rica, with a combined installed capacity of 113.3 MW. The total installed capacity of SHP up to 10 MW in the country was 126.5 MW, including four inactive SHP plants or plants with an unknown status, increasing from 125.5 MW in 2018. The 2020 investigation for the current edition of the World Small Hydropower Development Report (WSHPDR) found that no decommissioning or construction of new SHP plants was held since the previous edition (Table 1). The minor changes in installed capacity are due to a new data review (Figure 3).[5,15]

The majority of SHP plants in the country are connected to the grid. Off-grid SHP plants with a capacity of 1–10 kW are used for self-supply or in remote national parks, providing electricity support for the Ministry of Environment and Energy (MINAE) environmental protection tasks, for instance in the Cocos Island and Mount Chirripó National Parks. Public services distribution companies and private owners hold most of the operational SHP capacity, 64 per cent and 31 per cent, respectively, while ICE holds 5 per cent. The National Lighting Company (CNFL), which is the Central Valley public services distribution company and an ICE subsidiary, owns most of the oldest SHP plants in the country. Some of these plants date back to the early 20th century and, thus, require refurbishment.[16]

The investigation for the current Report found that in 2020 there were 50 limited capacity hydropower plants (up to 20 MW) in operation with a combined capacity of 328.7 MW. The total installed capacity of SHP up to 20 MW was 353.2 MW, including five inactive and unknown status plants, increasing from 352 MW in 2018.[15,16] The minor changes in installed capacity since the WSHPDR 2019 are due to a data review.

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



Source: ICE,[5] WSHPDR 2019,[15] WSHPDR 2013,[17] WSHPDR 2016,[18] Hoes et al.[19]

Note: Data for SHP up to 10 MW.

Table 1. **List of Selected Operational Small Hydropower Plants in Costa Rica**

Name	*Installed capacity (MW)*	*Operator*	*Launch year*
Suerkata	2.7	Private	1995
Rebeca I	0.1	Private	1995
Rio Lajas	10.0	Private	1997
Poás I y II	1.9	Private	1997
El Embalse	1.5	Private	1997
Río Segundo II	1.0	Private	1998
Chocosuela I	8.0	COOPELESCA	1999
Caño Grande III	3.3	Private	1999
Peñas Blancas Mini Hydro	0.4	ICE	2002
Cote	7.0	CNFL	2003
Chocosuela III	5.0	COOPELESCA	2003
Genio	0.03	MINAE	2005
Páramo	0.01	MINAE	2008
El Encanto	8.0	CNFL	2009
El Ángel	3.4	Private	2012
Vara Blanca	2.5	Private	2012
Tacares	7.0	ESPH	2013
Olivier	0.01	MINAE	2015
El Angel Ampliación	5.6	Private	2016
Matamoros	3.6	Private	2016

Source: ICE,[9,12] CENCE[16]

No official local estimate of SHP potential exists for the country. ICE reports 7,651 MW as the total identified hydropower potential capacity, regardless of the plant size. In this Report, the identified hydropower potential regardless of plant size is assumed as the technical potential. Installed capacity accounts for 30 per cent of the estimated technical hydropower potential. Nearly 35 per cent of the undeveloped hydropower potential is concentrated in indigenous territories and 20 per cent in national parks and reserve forest.[12]

Similar to the WSHPDR 2019, the theoretical SHP potential capacity data come from the systematic high-resolution assessment of worldwide hydropower potential by capacity.[19] Total theoretical SHP potential capacity of Costa Rica is 7,373.5 MW, which is 28.9 per cent of the country's total theoretical hydropower potential capacity, regardless of plant size, totalling 25,535.9 MW.[19] The estimated value coincides with the total theoretical hydropower potential capacity, reported by ICE.[12]

The 2018–2034 Electric Generation Expansion Plan considered the addition of three private SHP plants totalling 19 MW for SEN in 2021.[12] However, due to environmental disputes, the projects were not executed.[20] In the last years, some municipal councils are becoming increasingly concerned about the environmental impact of hydropower and have even signed moratoriums on hydropower developments in their territories, including SHP.[21] The central Government has also signed a moratorium on hydropower development in high potential watersheds.[22]

SMALL HYDROPOWER PROJECTS AVAILABLE FOR INVESTMENT

The 2020 investigation for the current Report found 52 MW of SHP projects in the feasibility stage: 33 MW from public distribution service companies and 19 MW from private SHP projects with environmental disputes as stated before (Table 2). Private SHP project capital expenditure (CAPEX) ranges between 3,500 USD/kW and 3,800 USD/kW.[12] Two other potential SHP projects for future development are Rio Piedras and PAAM, which are part of other short-term water use infrastructure plans. The Rio Piedras project consists of a 7 MW powerhouse at the toe of a 40-metre-high dam that creates a 70 hm^3 reservoir. The civil works are part of the Rio Piedras Multipurpose Project, a water storage project for crops irrigation and water supply in the Northern Pacific region.[23] The PAAM project consists of a 2.6 MW powerhouse installed in a new water supply pipe, for the Fifth Expansion Stage of the Metropolitan Water Supply System (PAAM).

Table 2. **List of Selected Small Hydropower Sites Available for Development in Costa Rica as of 2021**

Name	*Potential capacity (MW)*	*Type of site*
Futuro	10.0	New
Toro Amarillo 1	8.0	New
Llano Bonito	1.0	New
Rio Piedras	7.0	New
PAAM	2.6	New

Source: ICE,[9,12] CENCE[16]

RENEWABLE ENERGY POLICY

At the international level, Costa Rica has committed to the Paris Agreement and in 2020 updated its Nationally Determined Contributions (NDC), with higher ambitions for 2030. Costa Rica has also committed to adopt integrated climate actions, including mitigation and adaptation for 2030. Moreover, the country seeks to achieve the 2030 Agenda for Sustainable Development, with actions leading to increase the share of renewable energy in the overall energy mix, ensure energy access and increase energy efficiency (Sustainable Development Goal 7).

The national renewable energy policies of Costa Rica are defined in the National Energy Plans, under the guidelines of the National Development Plan established by the Government. The main objective of the current VII National Energy Plan 2015–2030 is to achieve energy sustainability with low carbon emissions. The Plan contains short-, medium- and long-term goals, with defined time limits and responsible institutions.[24] The VII National Energy Plan 2015–2030 was updated in 2019, considering new policies, regulations and plans for the energy sector. These include the Organization for Economic Co-operation and Development (OECD) accession recommendations, National Decarbonization Plan 2018–2050, National Development and Public Investment Plan 2019–2022, Law 9518 on Incentives and Promotion for Electric Transportation, National Electric Transportation Plan 2018–2030, energy sector audits, current guidelines and stakeholders' proposals.[25]

The National Decarbonization Plan 2018–2050, launched in 2019, states a net zero emissions economy goal for 2050.[26] This plan outlines the way of transforming the economy of Costa Rica towards a development model based on bioeconomy, green growth, inclusion and the improvement of the quality of life of the citizens. For the energy sector, this means electrification of the transport and industrial sectors, which is expected to cause an increased electricity demand to be met via a resilient and low-cost electricity system.

In compliance with the National Energy Plan, ICE creates Electric Generation Expansion Plans. ICE planning for the electricity sector focuses on the pursuit of sustainable development, ensuring low use of fossil fuels, diversifying renewable energy sources, fomenting MER and lowering the cost of electricity. Planned capacity investments for the 2018–2035 period include mostly renewable sources, adding up to 653 MW: 286 MW from wind power projects, 165 MW from geothermal power, 155 MW from solar power and 47 MW from hydropower, including 19 MW from private SHP projects currently discarded due to environmental disputes. The main changes from previous Electric Generation Expansion Plans are due to the downward trend of electricity demand.[12]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

In 1990, Law 7200 authorized autonomous or parallel generation, defined as electricity produced from private and public cooperative companies with LCP plants, defined as hydropower plants or plants based on non-conventional sources with lower than 20 MW capacity. Fossil fuel thermal plants, coal or large-scale hydropower are defined as conventional sources, whose development is planned by ICE according to Law 449 and national energy policies. Law 7200 regulates Build-Own-Operate (BOO) contracts signed between ICE and local or foreign private investors, which include power purchase agreements (PPA) for a period of 20 years. BOO contracts are capped to 15 per cent of total electricity production.[9] Law 7508 increased the cap of private generation by an additional 15 per cent in 1995, through Build-Operate-Transfer (BOT) contracts. Similar to BOO contracts, BOT contracts include power purchase agreement (PPA) for 20 years.[27] As stated by Law 7200, ICE buys electricity from BOO and BOT contracts, according to the ARESEP tailored tariffs for these plants. The size of power plants is regulated by Law 7200: 20 MW maximum capacity under BOO contracts and 50 MW maximum capacity under BOT contracts with local and foreign private investors.[5,28]

The licensing process for BOO contracts is defined in Law 7200. ICE calls for LCP bids in compliance with the Electric Generation Expansion Plan. Private investors interested in hydropower LCP development submit eligibility applications. Licensing approval requires an ICE declaration of eligibility, a granted concession from the Water Department of the Ministry of Energy, a granted concession from ARESEP and the National Technical Environmental Secretariat (SETENA) declaration of an Environmental Viability Licence. An Environmental Viability Licence is granted following a staged procedure. Depending on the impact evaluation required in each stage of the process, the projects advance to further stages requiring more details on the environmental impacts and countermeasures. Existing and old plants are subjected to the same process.[29]

For BOT contracts ICE also calls for bids in compliance with the Electric Generation Expansion Plan. BOT contracts are assigned through public bidding with price competition and technical, economic and financial capacity evaluations of the bidders.[9] In 2003, Law 8345 authorized public services distribution companies to use available energy sources in the country for meeting the electricity demand in their coverage areas. The licensing process for public services distribution companies is defined by Law 8345. The main requirements are a granted concession from the MINAE Water and Energy Departments for projects with less than 60 MW of capacity and a SETENA declaration of an Environmental Viability Licence.[30]

Since the global financial crisis in 2008, the electricity demand has demonstrated a downward trend, mainly due to economic factors. Several projects already defined between 2008 and 2015 were commissioned, leading to a surplus capacity that can support the country's electricity demand up to 2026, according to the Electric Generation Expansion Plan. Directive No. 68-MINAE for the energy sector was published in August 2020 to prevent electricity costs from rising. According to this Directive, the Ministry of Energy would not grant concessions or environmental permits for any type of new power projects for a one-year period to avoid an excessive installation of generating capacities, which could result in increased service costs.[31]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

In Costa Rica, SHP projects financing has been made by public and private commercial banks, national and international, as well as through trust funds. For projects regulated under Law 7200, loans above maximum credit limits for commercial banks can be authorized by the Central Bank of Costa Rica (BCCR). Tax exemption applies to imported machinery, waterway equipment and all equipment required for electricity generation.[9] For projects regulated by Law 8345, loans exceeding USD 10 million per year can be authorized by BCCR. The same tax exemptions apply to Law 7200.[28] Moreover, several SHP plants were also financed by the Kyoto Protocol Clean Development Mechanism (CDM). Furthermore, Costa Rica participates in the Guacamaya SHP project funded under the CDM.[32]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

The Inter-American Development Bank (IADB) published in 2016 a study about growing hydropower vulnerability in Central America due to climate change. The study focused on climate change effects for the seven main hydropower plants of the region, one for each country. Based on the climate change models of the Intergovernmental Panel on Climate Change (IPCC) and the projected changes in inflows, the study forecasted for the 305 MW Reventazón hydropower plant in Costa Rica a 2.3 per cent increase in generation in 2030 and a 13.9 per cent decrease in generation in 2090. The corresponding economic impact is estimated to be between USD 22 million and USD 244 million.[33]

Similarly, local preliminary studies indicate that climate change (i.e., increased rainfall south of the Caribbean and Pacific Regions or decreased rainfall in the north of the Pacific and Central Regions) could generate losses for SEN of between USD 200 million and USD 314 million yearly. Generation by fossil fuel thermal plants could reach 15 per cent of total electricity generation in 2080 if the country does not harness local renewable energy sources.[34] The natural inflow energy from the SEN hydropower sources turned out to be the lowest in 2019, taking into consideration all available water inflow data since 1965.

Costa Rica has not defined any official adaptation measures for the SHP sector. However, for large-scale hydropower, ICE focuses on sediment management, to preserve reservoir capacities in the long term.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Nowadays, the SHP sector in Costa Rica represents 5 per cent of installed hydropower capacity and is mainly owned by private and public service distribution companies. In the last decades, SHP has constantly contributed to the electricity sector of the country. However, the future development of SHP is expected to encounter more limitations than in the past. According to the authors, the main barriers for future SHP development in Costa Rica are:

- Environmental: The municipal and Government moratoriums on hydropower development in high-potential watersheds were put in place due to environmental concerns of the impact of SHP.
- Run-of-river seasonality: Currently, the share of renewable energy in the energy mix is highly influenced by the hydropower generation pattern. SHP plants are mainly run-of-river, thus, producing surplus electricity in the rainy season and providing less electricity in the dry season. Therefore, diversification of the energy mix is required for providing renewable electricity during the low season of hydropower generation.
- The improved competitiveness of solar and wind power projects: Solar and wind power projects have seen their CAPEX plummet dramatically in the last decade. Additions of these resources may reduce the operational marginal costs of SEN during the low season of hydropower generation, thus reducing the overall operating expenses (OPEX) of the SEN.
- Downward trend of the electricity demand: Electricity demand has been very low in the last years in Costa Rica. The existing installed capacity is enough for meeting the demand for the next years, therefore, there will be no need for new projects until 2026. To prevent electricity costs from rising, Directive No. 68-MINAE, published in August 2020, dictates that MINAE must not give concessions, nor environmental permits for any type of new power projects for a one-year period.

According to the authors, the main enablers for future SHP developments are:

- Technical know-how: Through the installed hydropower capacity and over 60 years of its existence, the sector accumulated strong experience with high-skilled staff, companies and all the necessary features for future environmentally sustainable and cost-effective hydropower development.
- SHP potential: There is a significant untapped potential for the development of SHP projects, which represents a sustainable way to harness the untapped hydropower potential in the country.
- Renewable energy policies: Energy policies encourage the development of renewable energy projects. Environmental and cost-competitive SHP projects (e.g.,

projects that can take advantage of existing and/or multipurpose planned facilities) may be interesting to fulfil the renewable energy share.

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El Salvador

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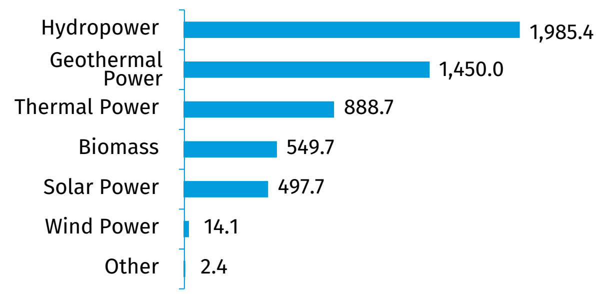
KEY FACTS

Population	6,704,864 (2019)[1]
Area	21,040.8 km^2[1]
Topography	The topography of El Salvador is dominated by parallel mountain ranges stretching from east to west and separated by a central plateau, which together comprise 85 per cent of the territory of the country. A narrow coastal plain extending to the Pacific Ocean accounts for the remaining 15 per cent. The highest point in El Salvador is Santa Ana in the southern mountains, at 2,365 metres above sea level.[2]
Climate	The climate in El Salvador is tropical and is characterized by two seasons — a dry season from November to April and a rainy season from May to October. The annual average temperature is estimated at 26 °C. During summer, temperature usually varies between 26 °C and 30 °C, while in winter it only drops to approximately 21 °C to 24 °C.[3]
Climate Change	Climate change models predict a rise in temperatures of 1.5–2.0 °C by 2040–2050 and of 2.5–4.5 °C by 2091–2100, relative to the 1961–1990 baseline period. The eastern parts of the country are expected to experience the most significant increases in temperature. Rainfall is expected to decrease by as much as 20–35 per cent by the end of the century.[4]
Rain Pattern	Average annual precipitation in El Salvador is 1,865 mm and can reach 2,000 mm in certain mountainous parts of the country. The variation in rainfall between the driest and the wettest months is approximately 227 mm.[2,3]
Hydrology	El Salvador has 11 hydrographic regions that are delimited by the basins of the country's main rivers. One of the most important is the Lempa River region, with an area of 10,082 km^2, which represents approximately 48 per cent of the national territory.[5]

ELECTRICITY SECTOR OVERVIEW

The total installed electricity capacity of El Salvador was 2,360.2 MW in 2020. Thermal power from fossil fuels provided 771.1 MW (33 per cent) of the total, hydropower provided 573.8 MW (24 per cent), solar power provided 474.5 MW (20 per cent), biomass provided 293.6 MW (12 per cent), geothermal power provided 204.4 MW (9 per cent), wind power provided 36.0 MW (2 per cent) and biogas provided 6.9 MW (less than 1 per cent) (Figure 1).[6]

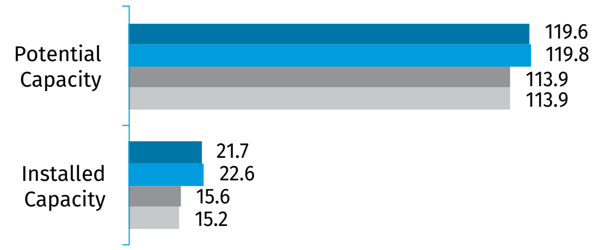
Figure 1. **Installed Electricity Capacity by Source in El Salvador in 2020 (MW)**



Source: SIGET[6]

Generation of electricity in 2020 amounted to 5,387.9 GWh. Hydropower contributed 1,985.4 GWh (37 per cent) of the total, geothermal power contributed 1,450.0 GWh (27 per cent), thermal power from fossil fuels contributed 888.7 GWh (16 per cent), biomass contributed 549.7 GWh (10 per cent), solar power contributed 497.7 GWh (9 per cent), wind power contributed 14.1 GWh (less than 1 per cent), and other sources contributed an additional 2.4 GWh (less than 1 per cent) (Figure 2). Total electricity generation increased by nearly 4 per cent relative to 2019. Generation from solar power increased nearly 130 per cent, while generation from fossil fuels decreased by approximately 45 per cent.[6] Approximately 85 per cent of electricity generation in 2020 was provided by renewable energy sources (RES), but this figure varies from year to year due to differences in weather, particularly in rainfall. The gap between generation from biomass and installed capacity of biomass-fired power plants is explained by the fact that biomass (bagasse) fuel is sourced from sugar cane and the plants operate only during the sugar cane harvest season between November and April rather than year-round.

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



Source: SIGET[6]

The electricity grid of El Salvador is composed of the high-voltage transmission network (above 115 kV) and the mid/low-voltage distribution network (below 115 kV). The transmission network in 2020 consisted of 41 115 kV lines with a total length of 1,073 kilometres, 24 substations and four 230 kV lines that interconnect the transmission system of El Salvador with that of Guatemala (14.6 kilometres) and Honduras (92.9 kilometres). The distribution of electricity is carried out by eight different companies supplying energy at different voltages. The overall length of the distribution lines is over 48,000 kilometres and the system supplied electricity to 1,907,939 end users as of the end of 2020.[6]

Access to electricity in El Salvador in 2020 was nearly 98 per cent nationwide, 99 per cent in urban areas and 95 per cent in rural areas.[7] Efforts have been started to develop a master electrification plan to provide technically and economically feasible solutions for communities still lacking electricity access. Electricity consumption in 2020 was 5,915.9 GWh, decreasing from 6,361 GWh in 2019 due to the impact of the COVID-19 pandemic, while peak demand reached 1,010 MW. Transmission losses accounted for 1.8 per cent of total electricity supply. Electricity imports covered the gap between domestic generation and total electricity demand and reached 642.6 GWh in 2020, decreasing by 50 per cent relative to 2019.[6]

The electricity market of El Salvador is composed of the wholesale electricity market and the retail electricity market. The wholesale market is constituted by the Long-Term Contracts Market (CLP) and the Spot Market (MRS). In order to participate in it, the installed capacity of a power plant must be at least 5 MW and it can be connected to either the transmission or distribution network. To participate in the retail electricity market, the installed capacity of the power plant must be less than 20 MW and it can only be connected to the distribution network. Bilateral contracts can be signed in both markets (power purchase agreement), to commercialize the electricity generated.[8]

El Salvador is additionally part of the Regional Electricity Market (MER), which operates under the Framework Treaty of the Central American Electricity Market, approved by Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama in May 2000. Its general design conceptualizes the MER as a seventh market. The six existing country markets or national systems have agents authorized by the Regional Operator Entity (EOR) and carrying out international electric power transactions in the Central American region.[9] All member countries are interconnected through the Central American Electrical Interconnection System (SIEPAC) transmission network.

Historically, as in many other countries in Latin America, the energy sector in El Salvador was first developed by the state. The electricity market was vertically integrated, with the activities of generation, transmission, distribution, commercialization and long-term planning of the energy sector being controlled and regulated by the state. Due to several policies implemented by the Government in the 1990s, the electricity market, among others, underwent reforms of laws and regulatory frameworks. As a result of these reforms, the electricity market became open to private investment and therefore changed to a competitive market. Its growth and development were driven by demand, which resulted in the state losing its role in the planning and strategic development of the sector.[9]

The first component of this reform was the approval of the Law of Creation of the General Superintendence of Electricity and Telecommunications (SIGET) and the General Law of Electricity. Both laws were approved by the Congress in 1996. The role of regulator of the electricity and telecommunications market was given to SIGET.[9]

The second component consisted of dissolving the state companies that operated the electricity sector. The activities of power generation, transmission, distribution, commercialization and operation of the electricity system were privatized. The National Council of Energy (CNE) was created in 2007, in an attempt to reinstate the strategic planning role of the state. CNE started operations in 2009 and established the National Energy Policy 2010–2024.[9] Aiming to accelerate the energy transition in El Salvador, in 2021 the CNE presented the new National Energy Policy 2020–2050, which includes the following strategic goals: regulatory modernization; sustainable energy supply; efficient energy consumption; research, development and innovation; and energy security and integration.[10]

The CNE is constituted by the ministers or vice-ministers of the government departments related to the different aspects of the energy sector's development, including the Ministry of Economy, the Technical Secretariat of the Presidency, the Ministry of Treasury, the Ministry of Public Works, the Ministry of Environment and Natural Resources and the Consumer Protection Agency.[9]

In addition to the CNE, the electricity sector is composed of the following agents:

- Electricity generating companies;
- The transmission agent (ETESAL), a private company responsible for the planning of the expansion, construction of new extensions and maintenance of the national transmission network;

- Private electricity distribution companies operating the low-voltage distribution networks;
- Electricity traders, private or public agents that perform selling and buying transactions in the domestic and regional electricity market to meet the demands of any other agent, including final users;
- The Transaction Unit (UT), an independent market and system operator in charge of operating the transmission system, maintaining the security of the system, ensuring a defined minimum quality of the services and supplies and also operating the wholesale electric power market;
- The SIGET is the regulatory entity responsible for applying the laws and regulations that govern the electricity and telecommunications sectors in the country.

The end user's electricity bill in El Salvador includes three charges: an energy charge, distribution charge and marketing charge. The energy charge is approximately 80 per cent of the bill and is adjusted quarterly based on Article 90 of the General Electricity Law Regulations. The adjustments are made on 15 January, 15 April, 15 July and 15 October of each year. The average unsubsidized prices of the electricity tariff to end users for the first semester of 2020 are presented in Table 1. The electricity subsidy applies to residential users with a monthly consumption of 1–105 kWh, for a value of USD 5.00 per month. For industrial consumers, the energy charge is calculated based on power level and not on consumption.

Table 1. **Electricity Tariffs in El Salvador in 2020**

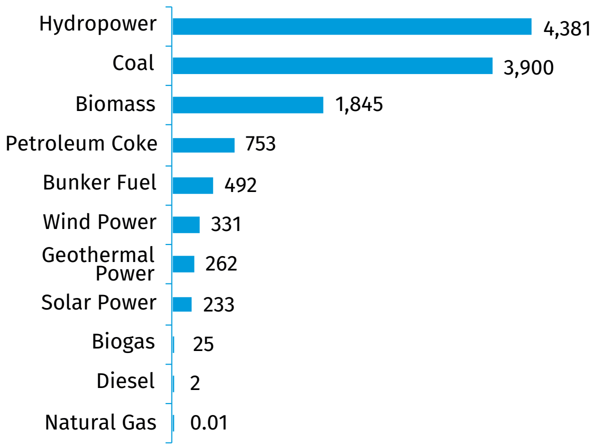
Tariff category	*Semiannual average price (USD/kWh)*
Low voltage:	
Total residential average	0.2018
General use	0.1773
Public lighting	0.1636
Medium demand (10–50 kW)	0.2234
High demand (> 50 kW)	0.2015
Medium voltage:	
Medium demand (10–50 kW)	0.1617
High demand (> 50 kW)	0.1442
Overall average price of distributors	0.1721

Source: SIGET[6]

SMALL HYDROPOWER SECTOR OVERVIEW

The definition of small hydropower (SHP) in El Salvador is a hydropower plant with an installed capacity off less than or equal to 5 MW.[11] The total installed capacity of SHP up to 5 MW in El Salvador was 21.7 MW in 2020; however, there are no SHP plants in the 5–10 MW range in the country, so the installed capacity for SHP up to 10 MW is the same. In addition, there are two non-operational plants with a combined capacity of 0.625 MW.[12] The potential undeveloped capacity for SHP up to 10 MW has been estimated at 97.3 MW by previous publications and for SHP up to 20 MW at 157.6 MW.[12,13,14] The total SHP potential up to 10 MW, including existing operational and non-operational plants and undeveloped potential, can therefore be estimated at 119.6 MW. Relative to the World Small Hydropower Development Report (WSHPDR) 2019, the installed capacity of SHP plants up to 10 MW decreased by approximately 4 per cent, while the estimate of potential capacity decreased by less than 1 per cent, in both cases due to a reassessment of the installed capacities and operational status of several existing plants (Figure 3).[13]

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



Source: García Méndez & Sagastume,[12] WSHPDR 2019,[13] JICA,[14] WSHPDR 2013,[15] WSHPDR 2016[16]

Note: Data are for SHP up to 10 MW.

A list of existing operational SHP plants in El Salvador is provided in Table 2. The current status of two previously operational plants, the 600 kW Atehuasías SHP plant and the 25 kW La Chacara SHP plant, is unclear, but they are likely inactive and in need of rehabilitation.[12] Two ongoing SHP projects on the San Simón River are listed in Table 3, while a list of several potential SHP sites available for investment is displayed in Table 4.

Table 2. **List of Existing Small Hydropower Plants in El Salvador**

Name	Location (river)	Capacity (MW)	Operator
Río Sucio	Sucio	4.20	COMPAÑIA ELECTRICA CUCUMACAYAN, S.A. DE C.V.
Cucumacayán	Sensunapan	2.80	COMPAÑIA ELECTRICA CUCUMACAYAN, S.A. DE C.V.
Nahuizalco I	Papaloate, Sensunapan, Las Monjas	2.80	SENSUNAPAN, S.A. DE C.V.

Name	Location (river)	Capacity (MW)	Operator
Juayua	Sensunapan	2.47	HIDROELÉCTRICA JUAYUA, S.A. DE C.V.
Papalote	Papalote	2.00	HIDROELECTRICA PAPALOATE, S.A DE C.V.
Milingo	Acelhuate	1.80	COMPAÑIA ELECTRICA CUCUMACAYAN, S.A. DE C.V.
La Calera	Santa Lucia, Calera	1.50	DE MATHEU Y COMPAÑIA, SOCIEDAD ANONIMA DE CAPITAL VARIABLE
San Luis I	Suquiapa	1.31	COMPAÑIA ELECTRICA CUCUMACAYAN, S.A. DE C.V.
Venecia Prusia	Acelhuate	0.75	INDUSTRIAS AGRÍCOLAS VENECIA Y PRUSIA, S.A. de C.V.
San Luis II	Suquiapa	0.74	COMPAÑIA ELECTRICA CUCUMACAYAN, S.A. DE C.V.
Bululú	Sensunapan	0.68	COMPAÑIA ELECTRICA CUCUMACAYAN, S.A. DE C.V.
Cutumay Camones	El Sauce	0.28	COMPAÑIA ELECTRICA CUCUMACAYAN, S.A. DE C.V.
Sonsonate	Sensunapan	0.15	COMPAÑIA ELECTRICA CUCUMACAYAN, S.A. DE C.V.
Velesa Energy	Agua Caliente	0.12	VELESA ENERGY S.A DE C.V.
El Calambre	Calambre	0.06	SANEAMIENTO BÁSICO, EDUCACIÓN SANITARIA Y ENERGÍAS ALTERNATIVAS
Miracapa	San Miguel	0.03	SANEAMIENTO BÁSICO, EDUCACIÓN SANITARIA Y ENERGÍAS ALTERNATIVAS
Junquillo	Quebada El Sirigual	0.02	SANEAMIENTO BÁSICO, EDUCACIÓN SANITARIA Y ENERGÍAS ALTERNATIVAS
Total		**21.71**	

Source: García Méndez & Sagastume,[12] Torres,[17] SIGET,[18,19] Hidroelectrica Juayua,[20] La Información[21]

Table 3. **List of Ongoing Small Hydropower Projects in El Salvador**

Name	*Location (river)*	*Capacity (MW)*	*Developer*
San Simón I	San Simón	0.23	ENSOSAL, S.A. de C.V.
San Simón II	San Simón	0.40	ENSOSAL, S.A. de C.V.

Source: SIGET,[18] IRENA[22]

Table 4. **List of Selected Potential Small Hydropower Sites in El Salvador**

Name	*River*	*Department*	*Potential Capacity (MW)*
El Sapo	Sapo	Morazán	2.4
Santo Domingo (Presa 1)	Tepechapa	Sonsonate	1.5
Santo Domingo (Presa 3)	Cacahuata	Sonsonate	1.5
Santo Domingo (Presa 2)	Quebrada El Camote	Sonsonate	1.5
Río Rosario - Metapan	Rosario	Santa Ana	1.0

Source: JICA[14]

RENEWABLE ENERGY POLICY

One of the strategic guidelines of the National Energy Policy 2010–2024 (NEP) is the diversification of the energy mix and the promotion of renewable energy resources. Since the implementation of the NEP, several adjustments have been made in the legal and regulatory frameworks of the electricity and environmental sectors as well as to taxation regulations to foster the development of renewable energy generation projects. The most significant adjustments include the following:

- The Law of Fiscal Incentives for the Promotion of Renewable Energy in Electricity Generation. The law establishes the type and duration of the fiscal benefits granted by the state to encourage the construction of new renewable energy power plants.
- The categorization of the environmental impact of activities, works or projects in the energy sector. Its purpose is to determine if a project requires an Environmental Impact Study (EIS) before its implementation.
- The Rules of Bidding Processes for Long-Term Contracts Supported with Renewable Distributed Generation establish the rules to follow in the implementation of this kind of public bidding processes.
- The Standard for End Users that Generate Electricity with Renewable Resources establishes the rules to follow by the end users for installing small power generation systems for self-consumption and the retribution model for sporadic energy injections in the distribution network.[13]

COST OF SMALL HYDROPOWER DEVELOPMENT

The Japan International Development Agency estimated the cost of SHP development in El Salvador in a 2012 Master Plan study for the development of RES in the country. The study proposed a three-phase programme for realizing the potential of the 123 identified SHP sites, with costs per phase ranging between 2,761 USD/kW and 3,391 USD/kW and with an overall average cost of 2,972 USD/kW.[14]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

El Salvador has taken significant steps at the regulatory and institutional level to promote the development of hydropower plants (and RES in general). Nevertheless, structural issues that may hinder development still persist, including the following:

- Lack of accurate hydrological data;
- Outdated estimates of SHP potential;
- The period to obtain a concessions permit is not clearly defined and induces uncertainty in the development process;
- Potential social opposition to SHP projects;
- The high investment costs of SHP in El Salvador compared to competing RES technologies;
- Few domestic options for financing SHP plants.

The key enablers of SHP development in the country are:

- Several detailed studies of SHP potential and inventories of potential SHP sites in the country have been conducted, although the collected data are not up-to-date;
- Significant unrealized SHP potential remains.

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Guatemala

Jonas Dobias, Water and Energy Independent Consultant

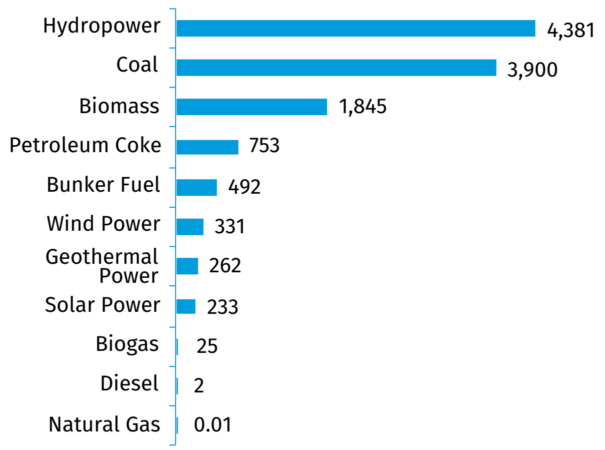
KEY FACTS

Population	16,850,000 (2020)[1]
Area	108,889 km^2[2]
Topography	A tropical plain of approximately 48 kilometres in width parallels the Pacific Ocean. Guatemala also has a piedmont region, which rises to altitudes of 90–1,370 metres. Nearly two-thirds of the country lies above these regions, in a mountainous, volcanic area stretching from the north-west to the south-west. The highest peak is Tajumulco (4,211 metres). To the north of the volcanic belt lies the continental divide and, even further north, the Atlantic lowlands.[2]
Climate	Guatemala is divided into three climatic zones. Daytime temperatures can reach as high as 40 °C and temperatures at night rarely drop below 20 °C. At approximately 1,000–2,000 metres above sea level lies a zone with temperatures rarely exceeding 30 °C. Daytime temperatures there are only slightly lower than in the temperate zone; however, the nights are rather cold and temperatures can drop below freezing.[2]
Climate Change	Due to climate change, the temperatures are projected to increase by 2.1–4.5 °C by 2050 and by 3.3–5.4 °C by 2070. Precipitation is expected to decrease by 9.5–12.4 per cent and 18.4–28.9 per cent for the same periods.[3]
Rain Pattern	Precipitation varies across the dry (May to October) and wet (November to April) seasons. The average annual rainfall in Guatemala for the period 2001–2016 was approximately 1,967 mm.[4]
Hydrology	In terms of hydrology, the country can be divided into three main areas. The Pacific Rim comprises 18 river basins. The coast on the Caribbean Sea, which includes the most important river, the Motagua, comprises 10 basins. There are also 10 basins in the Gulf of Mexico region, home to the most abundant rivers in the country.[2]

ELECTRICITY SECTOR OVERVIEW

In 2019, total electricity generation in Guatemala was 12,224 GWh, of which 2,102 GWh were exported, mainly to the Regional Energy Market (MER), formed by Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama. A small portion was exported to Mexico. At the same time, 1,068 GWh were imported from the MER and Mexico. Hydropower accounted for 4,381 GWh of total domestic generation, followed by 3,900 GWh from coal, 1,845 GWh from biomass, 753 GWh from petroleum coke, 492 GWh from bunker fuel, 262 GWh from geothermal power, 331 GWh from wind power, 233 GWh from solar power, 25 GWh from biogas, 1.66 GWh from diesel and 0.01 GWh from natural gas. Hydropower was the main source, accounting for approximately 36 per cent of the generation in 2019 (Figure 1).[6]

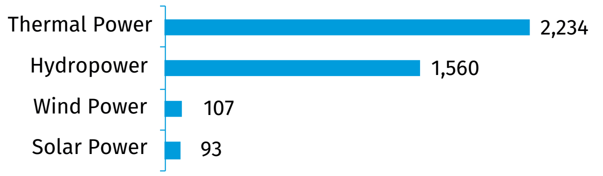
Figure 1. **Annual Electricity Generation by Source in Guatemala in 2019 (GWh)**



Source: AMM[6]

In 2019, the total installed capacity of Guatemala was 3,993 MW and available capacity stood at 3,415 MW. Of the total installed capacity, combustion (coal, diesel, bunker fuel and biomass) accounted for 56 per cent, hydropower for 39 per cent, wind power for 3 per cent from and solar power for 2 per cent (Figure 2).[6]

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



Source: AMM[6]

The total electrification rate in the country in 2019 was above 92 per cent.[6] However, there is a big gap between the more urban departments and the departments with high rural population. Guatemala is divided into 22 regions and each region, in its turn, is divided into municipalities, with a total of 340 municipalities in the country. Fourteen regions have an electricity network coverage of above 95 per cent; four of approximately 90 per cent; two of between 80 per cent and 85 per cent; one of approximately 68 per cent and one of 44 per cent.[7] The lowest electrification rate is recorded in the northern area, where the lowest economic indicators are shown.

Since 1998, the electricity sector in Guatemala works as an open market, where the Wholesale Market Administrator (AMM) has two products for transactions: electric power (MW) and electricity (MWh). There are two procedures for these transactions. The first one is based on prices fixed in mid- and long-term contracts; this is where most of the transactions are completed. The second one is executed through the AMM, where the transactions are based on costs set by the Regulation of the Wholesale Market Administrator (RAMM) rather than on market prices.[5] Electricity generating companies set their own electricity costs and the AMM calls them for dispatching in an order from the lowest to the highest cost on the spot market.

The electricity sector in Guatemala is unbundled, involving both state and private players, known as electricity market agents, who are active in the generation, transmission, trading and distribution segments. The electricity sector planning in Guatemala is overseen by the Ministry of Energy and Mines (MEM), while the National Electricity Commission (CNEE) is in charge of regulation. Energy dispatching is operated by the non-governmental organization AMM.

The state-owned company INDE owns 14 per cent of the total installed capacity, mainly hydropower, while the other 86 per cent is owned by the private sector. In total, there are eight transmission companies. The largest one is operated and owned by INDE (over 75 per cent of the total), while the other seven are privately-owned, of which one owns the regional line of SIEPAC. There are 19 distribution companies. One belongs to INDE and provides services to 42 per cent of users, two private companies provide services to 51 per cent of users and 16 municipal companies provide services to the remaining 7 per cent of users.[8]

The electricity tariffs in Guatemala are set by the CNEE every five years. These are adjusted every three months based on the electricity bought by the distributor, cost of electricity transmission and the distribution taxes (Table 1). In general, the price of electricity depends on the exchange rate the US dollar, international fuel prices and current hydrological conditions. Households that consume less than 300 kWh per month receive a subsidy from the state through INDE. A street light service cost is added to every user according to the municipality tariffs.

Table 1. **Electricity tariffs in Guatemala, May–July 2020**

Company	*Social tariff (USD/kWh)*	*Regular tariff (USD/kWh)*
DEOCSA	0.23	0.25
DEORSA	0.22	0.23
EEGSA	0.16	0.17

Source: CNEE[9]

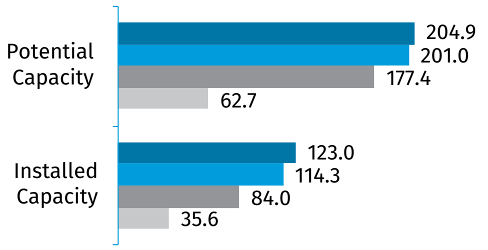
The Government plans to develop the electricity sector are enclosed in the following documents:

- The National Energy Plan 2017–2032, which is based on three axes: (i) sustainable use of natural resources; (ii) energy efficiency; and (iii) greenhouse gas emissions reduction.
- The Expansion Plan for the Generation and Transportation System 2018–2032, which, according to the RAMM Article 15, should cover a period of 10 years and be updated every 2 years.
- The Energy Policy 2019–2050, which is based on five axes: (i) electricity supply and use; (ii) fuel supply and use; (iii) energy efficiency; (iv) firewood use; and (v) sustainable development.
- The Expansion Plan for the Generation System 2020–2050, whose objectives are: (i) promotion of investments in electricity generation from renewable sources; (ii) promotion of natural gas, solar and wind power; (iii) focus on a strategic power system resilient to climate change; (iv) promotion of generation systems in areas where they do not currently exist; (v) integration of new energy sources into the transmission system. This plan also sets the objective to install approximately 60 power plants, from which seven are small hydropower (SHP) plants. The plan has also set three scenarios of annual electricity demand for 2050: low at 18,940 GWh, medium at 25,345 GWh and high at 42,510 GWh.
- The Rural Electrification Plan 2020–2050, which sets seven indicators for the selection of potential areas for rural electrification, the majority of which are off-grid. The plan also states an estimated investment cost for the implementation in each area.[10,11,12,13,14]

SMALL HYDROPOWER SECTOR OVERVIEW

In Guatemala, the definition of SHP refers to plants that have an installed capacity below 5 MW. In total, there are 74 SHP plants registered as a distributed renewable generator with MEM. Sixty-five plants are currently operating (123 MW), 33 are registered but are not operating (80 MW) and one is pending registration (1.9 MW). In comparison to the World Small Hydropower Development Report (WSHPDR) 2019, four new SHP plants have been commissioned with a combined capacity of 5.1 MW (Figure 3, Table 2). These started operating by the end of 2018 and the beginning of 2019.[14]

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



Source: WSHPDR 2016,[2] MEM,[15] WSHPDR 2013,[16] WSHPDR 2019[17]

Note: Data are for SHP up to 5 MW.

There is currently no accurate estimate of the SHP potential capacity in Guatemala. During the 1970s and 1980s, a Master Hydropower Plan for the country was developed, which estimated hydropower capacity at approximately 5,000–6,000 MW.[18] However, this capacity is only theoretical. Based on the combined capacities of operating, registered and pending-registration SHP plants, it can be assumed that there is at least 204.9 MW of SHP potential.

Most SHP projects in Guatemala are developed privately or through development assistance from international donors. The list of planned SHP projects to be connected to the national grid is shown in Table 3.

Table 2. **List of Selected Operational Small Hydropower Plants in Guatemala**

Name	*Location (department)*	*Installed capacity (MW)*	*Launch year*
La Mejana	San Marcos	1.00	2019
Hidrosan I	Chimaltenango	2.00	2018
Hidroxocobil	Retalhuleu	1.40	2018
Choliva	Chimaltenango	0.74	2018
Cutzan	Suchitepequez	1.95	2017

Source: AMM[19]

Table 3. **List of Selected Planned Small Hydropower Projects in Guatemala**

Name	*Location (department)*	*Capacity (MW)*
Pacayas	Alta Verapaz	5.00
CHT	Suchitepequez	4.50
Maxanal	Suchitepequez	2.80
San Luis	El Quiché	2.10
San Francisco	Quetzaltenango	0.40

Source: AMM[19]

There are micro-hydropower plants (below 1 MW) not connected to the national grid, which are generally located in remote rural areas and are directly operated by small local communities. Normally, these micro-hydropower plants have been funded by international cooperation programmes, which own their distribution grids that are not connected to the national grid. In addition, some municipalities have their own plants. Most, if not all, of them are old and out of service due to lack of maintenance. In some cases, they are damaged due to natural catastrophes, such as floods, resulting from hydrological extreme events. Although there are no concrete plans, some of these already have a prefeasibility study.

SMALL HYDROPOWER PROJECTS AVAILABLE FOR INVESTMENT

There is no official list of selected SHP sites available for development. However, the author of this chapter, as a technical adviser and hydrologist for MEM and CNEE, was responsible for the technical evaluation of three municipal hydropower plants that are currently out of service (Table 4).

Table 4. **List of Selected Small Hydropower Projects Available for Development in Guatemala**

Name	*Location (department)*	*Potential capacity (MW)*	*Type of site*
La Castalia	San Marcos	2.0	Reconstruction
Panzos	Izabal	0.5	Reconstruction
Polinsipec	Alta Verapaz	0.4	Reconstruction

Source: Dobias[20]

RENEWABLE ENERGY POLICY

The sustainable use of renewable energy resources is included in the first axis of the National Energy Plan for 2017–2032, the Guatemalan Climate Change Framework Law and the National Policy on Climate Change.[10,21,22] Furthermore, the promotion of investment into renewable energy technologies and of a strategic power system resilient to climate change are specific objectives included in the Expansion Plan for the Generation System 2020–2050.[13] The Plan also includes the construction of 60 hydropower plants, of which 6 are SHP plants. The aforementioned plans also align with international agreements, such as the United Nation Framework Convention on Climate Change (UNFCCC), the Paris Agreement and the Nationally Determined Contributions (NDCs). Concerning the latter, Guatemala has committed to an 11.2 per cent reduction of its carbon emissions by 2030 (or 22.6 per cent provided it can count on the technical and economic assistance from international donors). This reduction is focused on five sectors for mitigation actions, including the energy and transport sectors.[23]

Furthermore, the Rural Electrification Plan 2020–2050 has set the objective of reaching a 93.5 per cent electrification rate by 2023. The plan also describes the potential use of micro-hydropower plants (5–100 kW) and micro-grids in remote areas.[14]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

There are no specific government plans or programmes targeting SHP. However, the National Energy Plan 2020–2050 and the Expansion Plan for the Generation System 2020–2050 call for the implementation of small and micro-hydropower plants of up to 5 MW and 1 MW of capacity, respectively. Furthermore, the Technical Norm for Generation of Renewable Energy and Self-Producers with Energy Excess (NTGDR) is another example of regulations focusing on small-scale renewable energy plants (up to 5 MW). The NTGDR describes that SHP and other renewable energy plants can sell their electricity to the national electricity market or sell directly to the distribution companies.[24]

The development of hydropower below 5 MW does not make use of the national grid. Therefore, such projects do not require an authorization from MEM. However, they must be registered with MEM, as established in Article 8 of the General Electricity Law.[25] Such projects must be completed with several requirements, such as an Environmental Impact Assessment or an Environmental Flow Design from the Ministry of Environment and Natural Resources (MARN) to obtain the Environmental Licence. They also have to fulfil other requirements from different institutions, including the localization and forestry management documentation from the National Committee for Protected Areas (CONAP) and the National Institute for Forestry (INAB), respectively, as well as connection authorizations or studies from CNEE, AMM and INDE.

Overall, SHP development in the country is facilitated by a developed system of institutions responsible for registering, granting licences and conducting connection studies for SHP development projects are:

- MEM, responsible for the registration of SHP projects, national and official publication of renewable energy regulations, including tax incentives for renewable energy projects. MEM is currently developing a model for hydropower development, which requires developers to comply and align with the International Labour Organization (ILO)'s "C169, Indigenous and Tribal Peoples Convention";
- CNEE, responsible for the authorization of connection to the main electric grid;
- AMM, responsible for the required study to be incorporated in the energy wholesale market;
- INAB, responsible for the certification for forestry management;
- CONAP, responsible for the certification stating that the project is not developed in a protected area;
- MARN, responsible for environmental impact assessments.

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

INDE is one of the biggest financial sources for the implementation of rural electrification projects. At the moment of writing of this chapter, INDE was evaluating the possibility to receive a loan of USD 100 million from the Inter-American Development Bank (IDB) to finance and execute the Rural Electrification Plan 2020–2050.[14] Another mechanism aimed to promote the development of renewable energy in the country is the Law on Incentives for Renewable Energy Development, which exempts equipment and machinery used for renewable energy projects from custom tariffs. The law also provides tax exemptions during the first 10 years of operation of such projects.[26]

In previous years, the programme called Green Micro, Small and Medium Enterprises (MIPYMES Verde) used to be the main financial mechanism for the development of SHP in the country. The programme concluded in 2017. However, a second phase is planned to promote the development of renewable energy projects (solar power, hydropower, wind power, biomass and biogas) under 5 MW of installed capacity, for which a reimbursable fund of approximately USD 40 million is available. Nevertheless, as of 2021, due to the COVID-19, the status of the programme remained uncertain.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Currently, Guatemala has not established any climate change adaptation measures for SHP plants in its regulation. However, projects may establish their own adaptation measures.

During a workshop on climate change and its effects on hydropower generation organized by CNEE in 2014, four national experts on hydrology for hydropower were invited to discuss the threats that climate change presents to hydropower development. They also discussed the potential options to minimize the negative impacts. One of the conclusions was that, considering the expected increases in temperatures and decreases in precipitation, the estimated potential of hydropower in the country (5,000–6,000 MW) may be lower in the near future. Furthermore, it was also concluded that an increase in the density of the grid of hydrological and climatic gauges in the country is needed.[18]

Furthermore, the IDB and the Latin American Organization for Energy (OLADE) developed a study called "Vulnerability of the Hydropower System due to Climate Change in Central America and Adaption Options". The study analyzed one main hydropower plant in each country and concluded that, despite climate change being a menace in the region, hydropower will still be a viable option for energy supply in the region. However, it recommended that new projects should consider the variability of the climate in the short, mid and long term.[27]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Some barriers to the development of SHP and hydropower in general in Guatemala are:

- Environmental and social opposition to the development of hydropower. For this reason, the MEM has developed a methodology for consulting local populations based on the ILO Convention C169;
- In some cases, the hydropower potential is located far from the main grid (distribution or transmission lines) and connection lines turn out to be very expensive relative to the whole hydropower project;
- Economic and financial limitations, particularly for off-grid hydropower in rural communities, where international cooperation and assistance is the main funding source.[28]

The key enablers for further SHP development in the country include:

- A developed system of institutions responsible for registering, granting licences and conducting connection studies for SHP projects;
- Available undeveloped potential;
- Government policy conducive to renewable energy development.

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Honduras

Laura Stamm, International Center on Small Hydro Power (ICSHP)

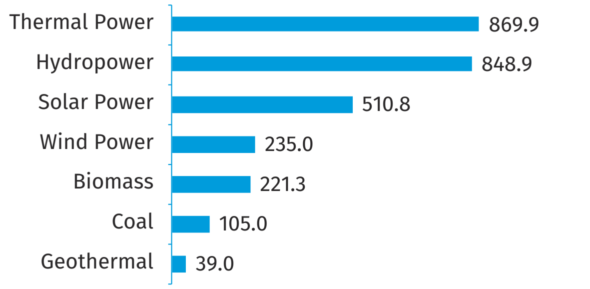
KEY FACTS

Population	9,904,608 (2020)[1]
Area	112,491 km^2 [2]
Topography	The Central American Cordillera Mountain Range sweeps the country east to west so that more than 75 per cent of the country's surface area is mountainous. The highest altitudes are found in the western region, where the country's highest point, Cerro Las Minas at 2,870 metres, is situated. The Volcanic Highlands are to the south-west. Very narrow plains can be found along the southern coast of the Gulf of Fonseca that opens to the Pacific Ocean. The northern coast with the Caribbean Sea has slightly wider plains, particularly in the north-eastern lowland region known as La Mosquitia.[3,4]
Climate	The climate in Honduras is temperate in the interior mountain areas and tropical near the coasts. Average temperatures in the highlands are between 19 °C and 23 °C with the highest areas being cooler, at approximately 14°C. Average temperatures in the coastal lowlands are between 26 °C and 28 °C, but are usually higher between May and November. The Caribbean coast remains hot and humid throughout the whole year, but the Pacific coast has a dry period between December and April when temperatures can be slightly cooler.[3]
Climate Change	In the past 50 years, average temperatures in Honduras have increased by approximately 0.4 °C and extreme weather events have also considerably increased. In 2015, German Watch's climate risk index classified Honduras as the country most affected by extreme weather events caused by climate change during the 1994–2013 period. These trends are expected to continue, specifically regarding the prevalence of hurricanes experienced by the country. Average temperatures are expected to rise by between 2.1 °C and 4.6 °C by the end of the century, with the interior highland region being most susceptible to the highest increase. A decrease in average rainfall is also anticipated.[5]
Rain Pattern	The rainy season throughout the country is generally from May to November. The northern coastal region experiences the most rainfall, between 1,800 mm and 2,800 mm annually. While rainfall happens all year long in this area, the heaviest rainfall and occasional hurricanes happen between June and November. Average rainfall in the southern coastal region is between 1,500 mm and 2,000 mm per year, almost all of which happens between May and November. Average rainfall in the interior mountain regions is between 1,000 mm and 1,800 mm annually.[3]
Hydrology	Honduras is a water-rich country. The majority of the waterways flow from the interior mountains to the north, emptying into the Caribbean. There are 14 significant rivers that produce approximately 82 per cent of the country's runoff that follows this path. The most important rivers that flow northwards are the Ulúa, Patuca and Aguán. These rivers often flood for a portion of the year and are at their lowest points between March and May. In the south, there are five rivers that flow from the interior and empty into the Pacific, and the Goascorán River is the most important of them. The rivers Lempa and Coco are considered border rivers, forming the borders with El Salvador and Nicaragua, respectively. The largest lake in the country is Lake Yojoa with an area of approximately 90 km^2, located within the western highlands.[6]

ELECTRICITY SECTOR OVERVIEW

At the end of 2021, total installed capacity in Honduras was approximately 2,830 MW, more than 65 per cent of which was renewable energy. Installed capacity of thermal power, mostly heavy fuel oil, was just under 870 MW (31 per cent). Hydropower accounted for approximately 849 MW (30 per cent), solar power for slightly less than 511 MW (18 per cent), wind power for 235 MW (8 per cent), biomass for just above 221 MW (8 per cent), coal for 105 MW (4 per cent) and geothermal power for 39 MW (1 per cent) (Figure 1).[7] There are three state-owned thermal power plants which comprise a combined 30 MW of installed capacity and six state-owned hydropower plants amounting to 537 MW. The remaining 2,263 MW of installed capacity is dispersed between numerous privately-owned plants. The largest single power plant is the state-owned Francisco Morazán hydropower plant with 300 MW of installed capacity.[7]

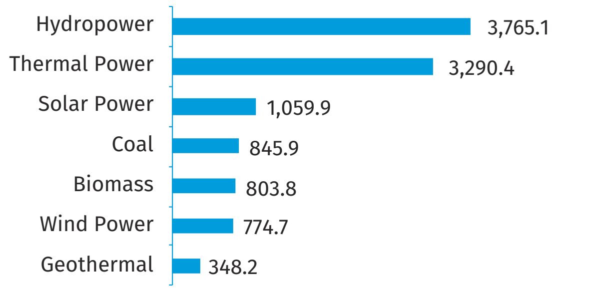
Figure 1. **Electricity Installed Capacity by Source in Honduras in 2021 (MW)**



Source: ENEE[7]

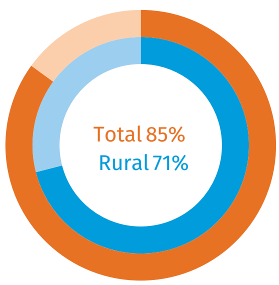
The total electricity generated in Honduras in 2021 was 10,888 GWh. Hydropower accounted for 3,765 GWh (35 per cent), thermal power generated 3,290 GWh (30 per cent), solar power 1,060 GWh (10 per cent), coal 846 GWh (8 per cent), biomass 804 GWh (7 per cent), wind power 775 GWh (7 per cent) and geothermal power 348 (3 per cent) (Figure 2). An additional 204 GWh was imported, most of which came from Guatemala.[7]

Figure 2. **Annual Electricity Generation by Source in Honduras in 2021 (GWh)**



Source: ENEE[7]

Figure 3. **Electrification Rate in Honduras in 2019 (%)**



Source: Government of Honduras[8]

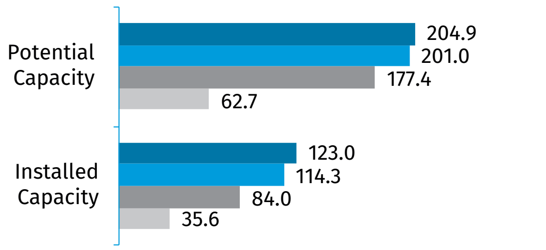
There is a considerable number of isolated rural communities throughout Honduras, particularly in the east, and many lack infrastructure connecting them to the more populous and urban epicentres in the west. This results in a contrast of electrification rates throughout the country. The overall electrification rate in 2019 was 85 per cent, with a 95 per cent urban electrification rate and 71 per cent in rural areas (Figure 3). Connection varies greatly throughout the rural areas, as the department of Gracias a Dios in the far north-eastern Mosquitia region has the lowest electrification rate of the country with less than 8 per cent.The state-owned National Company of Electrical Energy (ENEE) was originally created in 1957 in order to assume full responsibility of all the generation, distribution and transmission of electricity in the country. However, in the early 1990s, electricity demand grew at a faster rate than the ENEE could supply, which resulted in the passing of the Electricity Subsector Framework Law of 1994 which opened the sector for private companies to sell energy to ENEE. The law also created the National Commission of Electric Energy (CNEE) to oversee the contracts between ENEE and private companies. In 2014 full liberalization of the electricity sector emerged with the General Law of the Electric Industry, with the goal to improve efficiency through decentralization. Subsequently, the Regulatory Commission for Electric Energy (CREE) was established as a regulatory authority in the newly liberalized market. The Ministry of Natural Resources and the Environment (SERNA) grants environmental licences and oversees the sector as a whole.[8]

Electricity tariffs are set by CREE based on such factors as currency fluctuation, fuel prices and the state of the generation, transmission and distribution subsectors. Tariffs vary according to the type of consumer and usage and in January of 2022 prices per kWh ranged from USD 0.16 to USD 0.25.[9]

SMALL HYDROPOWER SECTOR OVERVIEW

Small hydropower (SHP) is defined in Honduras as hydropower plants with a capacity of up to 30 MW. In December of 2021, there were 45 SHP plants up to 30 MW with a combined installed capacity of 288.6 MW. Of these SHP plants, 37 had a capacity of up to 10 MW with a combined capacity of approximately 148 MW.[3] The total hydropower potential in Honduras is approximately 5,000 MW and the SHP potential up to 10 MW is estimated to be 385 MW (Table 1).[10] In comparison with data from the World Small Hydropower Development Report (WSHPDR) 2019, the installed capacity has increased by 20 MW, more than 15 per cent, due to the completion of new SHP plants, while the potential remained unchanged (Figure 4).

Figure 4. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in Honduras (MW)**



Sources: ENEE,[3] CIF,[10] WSHPDR 2013,[11] WSHPDR 2016,[12] WSHPDR 2019[13]

Note: Data for SHP up to 10 MW.

Table 1. **List of Selected Operational Small Hydropower Plants in Honduras**

Name	*Location*	*Installed capacity (MW)*
Sazagua Puringla	La Paz	10.0
Aurora	La Paz	9.0
Río Bertulia	Colón	8.3
Cuyagual	Santa Barbara	7.0
Chachaguala	Cortés	6.8
Nispero	Santa Barbara	6.0
Genera	Atlántida	5.2
Río Frio	Ocotepeque	3.9
Río Zingiuzapa	Francisco Morazan	3.1
Churune	Comayagua	3.0
Canjel	Santa Barbara	3.0
San Martín	Olancho	3.0
Corral de Piedras	Olancho	2.8
San Alejo	Atlántida	2.2
Coyolar	Comayagua	1.8
Matarras	Atlántida	1.7
Guineo	Olancho	1.4
Quilio	N/A	1.1
Agua Verde	Cortés	1.0
Peña Blanca	Cortés	0.9

Source: ENEE,[3] Bertrand & Álvarez[14]

Note: Data for SHP up to 10 MW.

RENEWABLE ENERGY POLICY

The first legislation that was passed with the goal to reduce the country's dependence on fossil fuels was the Law for Renewable Energy of 1998 under Decree No. 267-1998. This provided tax incentives for renewable energy generation up to 50 MW and obligated state company ENEE to purchase renewable energy at a maximum price. Tax incentives include exemption of import and sales tax and a five-year income tax exemption.[8,15] To further push for an increase in renewable energy, the Law on the Promotion of Electric Power Generation with Renewable Resources was passed in 2007. This augmented the incentives from the 1998 decree and included preferential tax and sales policies. It granted income and import taxes and dispatch priority of renewable energy on the grid.[13,16] Additional decrees in 2011 and 2013 further expanded on incentives for renewable energy. In particular, they:

- Created a registry of small renewable energy producers;
- Set transmission charges of 0.01 USD/kWh for renewable energy projects;
- Extended the incentives for renewable energy projects, such as exoneration of income tax, import duties and concession fees (except for hydropower) and tax credits on pre-investment expenditures;
- Extended the incentives to off-grid projects for distributed generation;
- Established net-metering for users under 250 kW;
- Established a special incentive for solar photovoltaics (PV) projects that had started operations before August 2015, fixing the duration of the 10 per cent incentive at 15 years and adding an extra premium of 0.03 USD/kWh. Limited to projects under 50 MW and not exceeding 300 MW of total installed capacity;
- Exonerated all renewable energy projects that provide an Environmental Impact Assessment (EIA) from construction permit fees.[13]

These initiatives are aimed at facilitating the transition of the energy mix in compliance with the provisions of the Country Vision and National Plan Law constituted into State Policy by Decree No. 286-2009. This law stated the goal to reach an energy mix composed of 60 per cent renewable energy by 2022 and 80 per cent renewable energy by 2038.[17] The goal to reach 60 per cent renewable energy has since been reached.

Rural electrification using renewable energy is a priority in Honduras. In 2012, the Honduras Scaling-Up Renewable Energy Programme in Low-Income Countries (SREP) was approved by the Inter-American Development Bank (IADB). This secured more than USD 30 million in grants and near-zero interest for a diverse programme of investment plans aimed at creating a more conducive environment for the renewable energy sector. Specific activities financed under the SREP include: a grid-connected renewable energy programme; a rural electrification strategy to accelerate electricity access in remote areas; promoting access to improved and appropriate cooking technologies; and a policy and regulatory reform initiative intended to improve the conditions for development of the country's renewable energy sector.[18] The SREP is an ongoing fund and as of 2021 was still accepting project requests. Recent activity includes a 2020 approval of the construction of 20 solar-powered mobile health units and an international bidding held in May of 2021 to supply goods and related services to constructing a mini-grid in isolated regions, including the least electrified department of the country.[19,20]

LEGISLATION ON SMALL HYDROPOWER

To develop SHP in Honduras, special licensing and permits granted by SERNA are required based on the size of the project, separated into three categories. For category 1 projects, between 0.5 MW and 1 MW, a Certificate of Environmental Registry must be obtained but has minimal requirements. Category 2 projects, between 1 MW and 3 MW, require an Environmental Authorization licence which calls for a qualitative environmental assessment amongst other requirements. Category 3 projects, above 3 MW, require an Environmental Licence and an EIA to be carried out at the site. For all projects, an additional contract of water is required.[21]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Some key barriers hindering the development of SHP in Honduras include:

- The equity capacity by private investors in Honduras is concentrated in larger, fossil fuel-based energy projects;
- The lack of road infrastructure and ancillary services markets;
- The need to invest in a transmission network.[13]

Some enablers that could encourage SHP development in the country:

- Full market liberalization allows for new entries into the market;
- Most of the total hydropower potential has not yet been utilized, leaving much opportunity;
- The low rural electrification rate in the country exhibits a need for more power plant developments, particularly in the eastern region of the country.

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Mexico

Sergio Armando Trelles Jasso, Mexican Institute of Water Technology (IMTA)

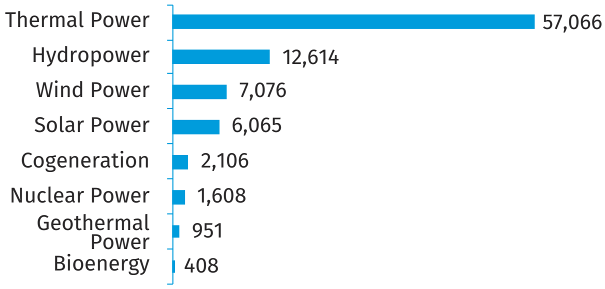
KEY FACTS

Population	126,014,024 (2020)[1]
Area	1,965,262 km^2 [2]
Topography	The relief of Mexico is characterized by several mountainous chains, including the Peninsula of Baja California (1,200 km long), Western Sierra Madre (1,400 km), Eastern Sierra Madre (600 km), Southern Sierra Madre (1,000 km), Sierra Madre of Oaxaca (300 km), Central American Mountain Range (with a peak altitude of 4,092 metres) and Neovolcanic Axis (with a peak altitude of 5,610 metres). The altitude of the Central High Plateau ranges from 500 metres to 2,600 metres. From these formations the altitude descends to the Northern Plateaus, the Sonora and Chihuahua Deserts and the coastal plains along the Pacific Ocean and the Gulf of Mexico. The Peninsula of Yucatan in the far south-east is a flat karst formation with almost no streams or rivers.[3]
Climate	The average temperatures range from 16 °C in the states of Tlaxcala and Mexico to 27 °C in the Peninsula of Yucatan.[4] The minimum temperatures, below -6 °C, occur in December and January in the northern mountainous areas. The maximum temperatures, above 48 °C, have occurred between April and July in the north-west, along the Pacific coast and the central parts of the country. There is a great diversity of climate: dry in most of the centre and north (28 per cent of the country); very dry in the north-west (21 per cent); warm and humid in the south (5 per cent); warm subhumid along the coasts (23 per cent); temperate humid in the mountains of the south (3 per cent) and temperate subhumid in the mountains near the coasts (21 per cent).[5]
Climate Change	Mexico is highly vulnerable to the effects of climate change, which impacts both human populations and ecosystems. It is expected that cyclones will be more intense in the north-west, as well as along the Pacific and Atlantic coasts. Strong storms are likely to become more frequent, increasing the risk of flooding. At the same time, most of the country is projected to become drier and drought frequency is also likely to increase, with a consequent increase in the demand for water.[6]
Rain Pattern	From 1981 to 2010, the average annual precipitation in the country was 740 mm. The spatial distribution varies greatly, from 98 mm in the Río Colorado to 2,220 mm in the Coast of Chiapas. Annual precipitation extremes range from 33 mm in the north-west to above 4,500 mm in the south-east.[7] The rainy season, from May to October, accumulates 83 per cent of the annual rainfall. Every year, between July and October, there are tropical storms and hurricanes that reach both littorals. From 1970 to 2015, there were 224 such events, most of them on the Pacific coast, but the strongest ones occurred on the Atlantic coast.[8,9]
Hydrology	The country is divided into 37 hydrologic regions, which are further divided into 158 river basins and 976 subbasins.[10] The total mean runoff is estimated at 354,990 hm^3 per year, equivalent to 180 mm per year across the entire country or approximately 21 per cent of the annual rainfall. Two thirds of the total runoff occur in seven river basins that cover 22 per cent of the surface of the country: Grijalva-Usumacinta, Papaloapan, Coatzacoalcos, Balsas, Pánuco, Santiago and Tonalá.[9]

ELECTRICITY SECTOR OVERVIEW

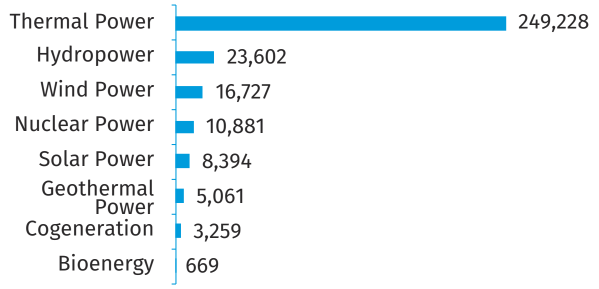
The total installed capacity of Mexico in 2020 was 87,894 MW, indicating a 12 per cent increase since 2019. Of this total, thermal power from fossil fuel sources contributed 57,066 MW (65 per cent), hydropower contributed 12,614 MW (14 per cent), wind power contributed 7,076 MW (8 per cent), solar power contributed 6,065 MW (7 per cent), efficient cogeneration contributed 2,106 MW (2 per cent), nuclear power contributed 1,608 MW (2 per cent), geothermal power contributed 951 MW (1 per cent) and bioenergy contributed 408 MW (less than 1 per cent) (Figure 1). Relative to 2019, there has been a marked increase in all forms of clean renewable energy, particularly solar power capacity, which increased by over 66 per cent. Conversely, hydropower installed capacity remained stable. The largest generating capacities are located in the states of Chiapas, Veracruz and Guerrero, while states with the smallest installed capacity include Morelos, Campeche and Mexico City.[11]

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



Source: SENER[11]

Figure 2. **Annual Electricity Generation by Source in Mexico in 2019 (GWh)**



Source: SENER[11]

There are four types of entities in Mexico that produce electricity and contribute to the total installed capacity. The state-owned Federal Electricity Commission (CFE) owns a 51 per cent share of the installed capacity, operating a variety of technologies including the country's only nuclear power plant. Independent power producers that sell all their production to CFE own 19 per cent of total capacity, primarily operating combined-cycle plants and some wind power plants. Private producers that are authorized to sell electricity on the open market own 28 per cent, operating combined-cycle plants and a variety of plants based on renewable energy sources (RES). Finally, the state-owned oil company PEMEX owns approximately 1 per cent of the total capacity, operating plants based on efficient cogeneration, conventional thermal power and gas turbine technologies.[11]

The total annual electricity generation in 2019 was 317,820 GWh, with thermal power providing 249,228 GWh (over 78 per cent) of this total, hydropower providing 23,602 GWh (7 per cent), wind power providing 16,727 GWh (5 per cent), nuclear power providing 10,881 GWh (3 per cent), solar power providing 8,394 GWh (nearly 3 per cent), geothermal power providing 5,061 GWh (nearly 2 per cent), efficient cogeneration providing 3,259 GWh (1 per cent) and bioenergy providing 669 GWh (less than 1 per cent) (Figure 2). The combined share of electricity generated from clean renewable and clean non-renewable sources was nearly 22 per cent of total generation.[11] It is also notable that nearly 59 per cent of electricity generated in 2019 was provided by combined-cycle and gas turbine plants, which import 90 per cent of the gas used for generation from the United States of America (USA).[12]

The National Electric System (SEN) is organized in nine regions, each with a control centre. Seven of the regions cover most of the territory of the country with dense electric transmission and distribution networks that constitute the National Interconnected System (SIN). The remaining two regions are on the peninsula of Baja California that has three regional networks: one on the north (BCN), linked to an electrical network in the USA; another in the south of the state (BCS); and the isolated network of Mulegé (MUL).

The electricity grid infrastructure comprises the National Transmission Network (RNT), which has 55,816 kilometres of high voltage transmission lines (230–400 kV), continued by 54,497 kilometres of high voltage subtransmission lines (69–161 kV) and the General Distribution Networks (RGD), which have 872,946 kilometres of medium- and low-voltage distribution lines (from 33 to less than 2.4 kV). As of 2021, the RNT possessed a transformation capacity of 165,713 MVA, while the transformation capacity of the RGD was 77,978 MVA.[11] The technical and non-technical losses in the SEN are estimated at 12 per cent. There is a programme in execution to control losses. The expectation is to limit the losses to 8 per cent in 2034, following the international standard.[13] There are ongoing projects across Mexico to expand the RNT and RGD to meet increasing electricity demand, improve reliability, reduce costs, and fulfill clean energy goals.

On the northern border, Mexico has 11 interconnections with the states of Texas and California in the USA, with capacities ranging from 36 MW to 800 MW. On the southern border, a transmission line of 103 kilometres at 400 kV linking Mexico and Guatemala started operation in 2010.[14] There are plans to connect this strategic link to the Central American Electrical Interconnection System (SIEPAC), traversing 1,800 kilometres at 230 kV with a capacity of 600 MW and serving six countries of the Regional Electricity Market of Central America.[15] In addition, Mexico has been connected to Belize since 1998 by a transmission line of 115 kV and 230 kV with a capacity of 65 MW, which supplies approximately 70 per cent of the demand in Belize.

To connect a new power plant with capacity equal to or greater than 0.5 MW to the grid, it is necessary for the National Centre of Energy Control (CENACE) to execute one or more technical studies to ensure the reliability of the electric system. These include an Indicative study, an Impact on the System study, as well as an expedited Installations Study and Impact Study. The cost and the duration of the studies vary depending on the capacity of the plant. For example, for a small hydropower (SHP) plant of up to 30 MW, the set of studies can cost approximately USD 49,000 USD and require up to 55 working days.[16]

CFE has plans to build, acquire or participate in the development of power generation plants in order to maintain its leadership in the sector and ensure a 54 per cent share of national electricity generation by 2027 is to be met through the addition of 13 thermal projects, with an estimated investment of approximately USD 10 billion.[13]

The national electrification rate in the first quarter of 2021 was nearly 100 per cent, although a small degree of variation in electricity access exists throughout the country, with Mexico City having the highest rate of access at over 99.9 per cent.[17] Due to the operating reserve margin, shortages of electricity on a regional or seasonal scale normally do not occur. Some outages of electric supply of short duration and limited extent may occur, caused mainly by strong winds or heavy rain events.[18] However, in the last decade there have been several outages caused by major natural disasters, accidents and the strong dependence on gas imports from the USA for electricity generation. The most significant outage occurred on 15 February 2021, caused by the disruptions to gas supply infrastructure in Texas, USA as a result of extreme weather. Notably, on that occasion power was restored in Mexico much earlier than in Texas because of the rapid increase in generation by hydropower plants located in the south-eastern part of Mexico.

Electricity consumption in Mexico is highest in August and lowest in February. The overwhelming majority of electricity (nearly 95 per cent) is consumed by users connected to the SIN, mainly in the Central, Western and North-eastern regions. The remainder is accounted for by the two regional networks, BCN and BCS, in Baja California. The final consumption by end users in 2019 equalled 274,917 GWh. Medium industry accounted for 38 per cent of this total, large industry for 25 per cent, residential users for nearly 25 per cent, commercial users for 6 per cent, agriculture for nearly 5 per cent and services for nearly 2 per cent. The maximum demand of capacity in 2019 was 45,946 MW. The threshold of 95 per cent of maximum demand was exceeded in 131 of the 8,760 hours of the year, while the load factor was 76 per cent.

The Secretariat of Energy (SENER) has analyzed three scenarios (high, planning and low) of the expected growth in the capacity demand and electricity consumption for the period 2020–2034. The national gross consumption in the SEN for 2034 under an assumption of 2.7 per cent yearly increase, is expected to reach 483,317 GWh, 49 per cent higher than in 2019. Similarly, final consumption is expected to grow at a yearly rate of 3.1 per cent. The maximum demand of coincident capacity in the SEN for 2034, assuming a 2.8 per cent annual increase, is expected to reach 73,790 MW, a 60 per cent increase relative to 2019.[11]

A process of radical reforms of the legal and institutional framework of the energy sector was initiated in 2013, focusing mainly on the oil and gas industry, but also targeting the electricity sector. As part of the reforms, Articles 25, 27 and 28 of the Constitution were amended, along with 12 national laws, while 9 new laws were adopted in 2014, with a subsequent adjustment or adoption of the corresponding bylaws.[19] Changes included the partial privatization of the electricity sector. Previously, the right to generate, transmit, transform, distribute and supply electric energy for public service was exclusive of CFE. Following the reforms, the Government remained responsible for the planning and control of the SEN as well as for the RNT and RGD, while private companies were allowed to participate in the generation and sale of electricity and associated products, with the exception of nuclear power and the supply of electricity to residential consumers. The roles of the main public institutions in the electricity sector were adjusted accordingly, including those of the SENER, CFE, Regulatory Commission of Energy (CRE), CENACE, Secretariat of Environment and Natural Resources (SEMARNAT), National Water Commission (Conagua) and National Commission for the Efficient Use of Energy (CONUEE).

CFE and PEMEX, the national oil and gas company, were redefined as state-owned productive enterprises, required to compete with private companies and additionally allowed to form public-private partnerships. CFE was divided into nine subsidiary enterprises and four affiliated enterprises. The generation capacity of CFE was split among six subsidiaries that compete with each other using a variety of energy sources, including one business unit for nuclear power.

The legislative approval of the 2013 Energy Reform was extremely controversial since its inception and revealed many conflicts of interest among the political forces promoting this reform. The administration of Andrés Manuel López Obrador, inaugurated in December 2018, declared its intention to review the Energy Reform of the 2013 with the aim of moderating the most detrimental effects, rather than enact a complete reversal. A Presidential proposal to amend the Reform on a constitutional level was rejected in a historic vote on 17 April 2022. However, earlier measures to mitigate some aspects of the Reform were adopted on 9 March 2021 as part of amendments to the Law of Electric Industry, and finally validated by the Supreme Court of Mexico on 7 April 2022.[20] These measures are intended to promote the CFE as the predominant actor in the electricity sector and include the following:

- Modifications to electric dispatch criteria to prioritize hydropower and all CFE-owned plants over private plants of all other technologies;
- Obligation of all energy sector contracts to comply with the planning criteria defined by SENER;
- Issuance of Clean Energy Certificates (CEL) regardless of ownership and date of start of operation, to now include CFE's clean energy plants;
- Eliminating the obligation of CFE to buy energy for basic supply through auctions;
- Revocation of self-supply generation permits deemed to be fraudulent;
- Revision of existing Government contracts with independent power producers.[21]

The Wholesale Electricity Market (MEM) was launched in 2016 and is supervised by CENACE. The products sold on the

MEM include electric energy, capacity balance, CEL, ancillary services (SC) and financial transmission rights (DFT), among others. Within the MEM, participants have the option to conduct deals on five markets: the Short-Term Energy Market, composed of the Day-Ahead (MDA), the Real-Time (MTR) and the Hour-Ahead (Spot) markets; the annual Capacity Balance market; the CEL market, held at least annually; the periodic DFT market; and the medium- (3 years) and long-term (15–20 years) auctions of Energy, Capacity and CEL.

Interested parties, either legal entities or natural persons undertaking entrepreneurial activities, can register in the MEM as market participants under six modalities: Generator, Qualified User, Supplier of Basic Services, Supplier of Qualified Services, Supplier of Last Resort and Non-Supplier Marketer. The only supplier for residential consumers is CFE-Basic Supply. Private companies can be generators, suppliers and marketers of electricity directly to qualified users. Qualified users of energy, with demands of 1 MW or more, are able to buy from the MEM, from suppliers of qualified services or directly from generators. Private companies are allowed to participate in the expansion and operation of the transmission and distribution networks. Energy marketers and qualified users must buy a minimum percentage of capacity, either continuous or interruptible.

The MEM is an hourly cost market. The final price depends on the marginal cost of generation. The price is regulated by SENER, CENACE and CRE. The hourly Local Marginal Prices of electricity (PML) are calculated at 2,536 local price nodes of the SEN (NodoP), taking into account an energy factor, system losses and congestion of the substations. These prices are published online.[22]

CELs have been issued and traded since 2018. There have been three long-term auctions awarding 15-year contracts for the purchase of clean energy and CELs in 2016 and 2017, mainly to solar and wind power projects. The resulting average prices of electricity have decreased from 41.80 USD/MWh to 33.47 USD/MWh, and then further to a price of 20.57 USD/MWh. The decrease in prices has been associated with commercial competition and the reduction of costs of wind and solar power projects. A fourth auction was called in 2018, but later cancelled in 2019. The price scheme for the electric transmission service has been adjusted to reduce subsidies.[23]

An important amendment to the Law of the Electric Industry (LIE) promoted by the President entered into force on 10 February 2021. One of the amendment's main provisions changed the priority assigned by CENECE in dispatching the generation of power plants: first priority was assigned to hydropower plants; second, to the rest of CFE's power plants; third, to wind and solar power plants owned by private producers; last, to combined-cycle and other power plants owned by private producers. Additionally, CELs will be issued to all plants generating clean energy, including CFE's large hydropower plants. The amendment also stipulated that the Suppliers of Basic Services, including CFE, will no longer be obliged to buy products through energy auctions. Previously, the CFE had been buying electricity at auctions at prices higher than the electricity generated by its own plants, in a form of public subsidy for private producers. Finally, new technical feasibility criteria for intermittent energy sources were introduced for the connection to the grid and the legality and profitability with regard to the national budget of all permits and existing contracts relating to self-supply generators and IPPs will be reviewed and renegotiated or revoked.[24] However, this amendment precipitated strong opposition from private developers and the struggle concerning its application is ongoing.

As per Article 12 of the LIE, the CRE holds responsibility for setting the electricity tariffs in Mexico, in addition to other legal powers, including the granting and modification of generation permits, determination of rules of payment of production to distributed generators, issuance of grid and basic supply tariffs, issuance of rules and supervision of the MEM, authorization of model contracts for MEM and interconnection of power plants, granting of CELs, establishing the definition and criteria of clean energy, defining the rules for clean energy generation and for capacity acquisition, authorization of energy auctions, expression of opinion on the expansion of RNT and RGD, authorization of standards of interconnection of power plants, authorization of imports and exports of energy, record keeping of MEM participants, regulation and supervision of the standardization process and fostering the training of personnel for clean energy generation.[24]

The electricity tariff structure established by CFE takes into account the connection voltage level, the category of use, the region, the season, the required and used demand, the required continuity, the type of energy source, the day of the week and the level and hour of consumption (base, intermediate and peak). Consequently, more than 40 different tariffs are in place for different connections and usage characteristics. In general, the highest tariffs are those of the Baja California and Baja California Sur regions, while the lowest are applied in the North Central, North-eastern and North-western regions. The tariffs are charged in Mexican pesos (MXN) and are indexed on a monthly basis.

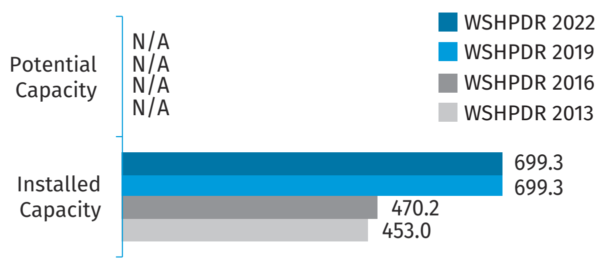
The transmission tariffs applicable to Qualified Users of the MEM for 2021 were: 76.3 MXN/MWh (3.74 USD/MWh) for connections up to 220 kV,and 173.7 MXN/MWh (8.53 USD/MWh) for connections below 220 kV.[23] The mean tariff for all users in November 2017 was 86.07 USD/MWh, assuming an exchange rate of 18.91 MXN/USD on 16 November 2017.[18] From that date, the federal Government has endeavoured not to increase the electricity tariffs at more than the official yearly inflation rate.

SMALL HYDROPOWER SECTOR OVERVIEW

There is no legal definition of SHP in Mexico. However, a hydropower plant is considered eligible for incentives aimed at promoting clean and renewable energy projects when its capacity is up to 30 MW or when it has a power density of at least 10 W/m^2, which is the ratio of installed capacity to water surface in the reservoir.[25] As of May 2019, CRE had issued 148 permits to existing hydropower plants or new projects, although six permits have subsequently been either revoked or terminated. Of the remaining 142 permits, 110 are permits for SHP plants up to 30 MW, including operational plants as well as ongoing and planned projects.[18,26]

There are 69 SHP plants in operation in Mexico with a combined capacity of 699.3 MW and an authorized annual generation of 3,193.2 GWh. Of this total, 32 belong to CFE and 37 to other private or public entities. All of the SHP plants in operation are connected to the national electric grid.[26] No official nationwide estimate of SHP capacity up to 30 MW is available. Relative to the World Small Hydropower Development Report (WSHPDR) 2019, both installed and estimated potential capacity have remained constant, as no new SHP plants have been commissioned (Figure 3).[27] A partial list of operational SHP plants in Mexico is provided in Table 2.

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



Source: CRE,[26] WSHPDR 2019,[27] WSHPDR 2013,[28] WSHPDR 2016[29]

Table 2. **List of Selected Existing Small Hydropower Plants in Mexico**

Name	*Location*	*Capacity (MW)*	*Annual generation (GWh)*	*Operator*	*Launch year*
La Boquilla	Chihuahua	25.00	81.5	Generadora Fénix	2016
Santa Bárbara	Estado de México	22.53	3.0	Generadora Fénix	2016
Oviáchic	Sonora	19.20	92.1	Generadora Fénix	2016
Camilo Arriaga	San Luis Potosí	18.00	84.5	Generadora Fénix	2016
N/A	Veracruz	16.94	132.0	Generadora Fénix	2016
N/A	Sinaloa	15.00	39.0	CFE - Generación I	2015
Gral. Salvador Alvarado	Sinaloa	14.00	41.0	Generadora Fénix	2016
Planta Orizaba	Veracruz	10.00	24.7	Generadora Fénix	2016
Mocúzari	Sonora	9.60	40.8	Generadora Fénix	2016
Puente Grande	Jalisco	9.00	24.0	Generadora Fénix	2016
N/A	Jalisco	8.00	30.5	Generadora Fénix	2016
Luis M. Rojas	Jalisco	5.32	10.0	Generadora Fénix	2016
Colina	Chihuahua	3.00	8.2	Generadora Fénix	2016
Portezuelos I	Puebla	2.80	13.7	Generadora Fénix	2016
Ixtaczoquitlán	Veracruz	1.60	11.0	Generadora Fénix	2016
Electroquímica	San Luis Potosí	1.44	8.4	Generadora Fénix	2016
Bartolinas	Michoacán	0.75	2.3	Generadora Fénix	2016
Micos	San Luis Potosí	0.69	2.7	Generadora Fénix	2016
Itzícuaro	Michoacán	0.62	3.9	Generadora Fénix	2016

Source: CRE[26]

Additionally, there are 41 SHP plants under construction or waiting to start construction with a combined capacity of 452.5 MW and an authorized generation of 2,277.0 GWh. One of these plants belongs to CFE and 40 to other private or public entities.[26] A partial list of ongoing SHP projects is provided in Table 3.

Table 3. **List of Selected Ongoing Small Hydropower Projects in Mexico**

Location	*Capacity (MW)*	*Annual generation (GWh)*	*Operator*	*Planned launch year*	*Development stage*
Guerrero	30.0	150.0	Mexicana de Cobre	2013	Construction
Veracruz	26.0	118.0	Hidroeléctrica Solís	2014	Construction
Noroeste	30.0	191.7	Generadora Fénix	2016	Construction
Guerrero	30.0	146.2	Proyectos Hidroeléctricos de Puebla	2016	To start works
Puebla	27.4	108.8	Industrias Wack	2017	To start works

Source: CRE[26]

Note: Data are from 2019

For several decades, CFE has been conducting planning studies focused on identifying potential hydropower sites with an expected production greater than 40 GWh/year. In 2012, its inventory included 585 such sites, including 73 plants now in operation. The combined potential capacity of the remaining 512 sites was estimated at 41,132 MW, with a potential generation of 114,754 GWh/year and an average utilization factor of 32 per cent.[30]

In 1995, CONAE published a national estimate of SHP potential in Mexico of approximately 3,250 MW, considering plants with a capacity of between 2 MW and 10 MW.[31] However, this assessment was based on an incorrect extrapolation from data on other countries. Subsequently, the author of the original estimate stressed the urgent need to conduct a more rigorous assessment of the national SHP potential.[32] Nevertheless, up until the present day many official and academic documents have continued to cite the figure of 3,250 MW as a fact.

Subsequently, SENER has published an estimate of the total probable SHP potential of 2,700 MW, based on the aforementioned studies carried out by CFE.[33] This value was based on the combined capacity of 489 sites picked from the 512 in the CFE inventory, raising the utilization factor to 100 per cent and reducing the height of the dams. The methodology applied was of questionable quality and this estimate is largely uncertain.

Furthermore, there have been several official assessments of the SHP potential in natural streams of certain river basins, which, however, cover only a very small portion of the national territory. These studies have a widely varying degree of hydrological and topographical precision. At the low end of the precision spectrum, in 1995 a study was commissioned by CONAE of six watersheds on the coast of the Gulf of Mexico, covering 26,376 km^2, where a total of 100 SHP sites were identified using simplified techniques and data.[32] At the high end of the spectrum are the studies commissioned by CFE in 2007 for three watersheds, covering 29,259 km^2, where a total of 3,118 micro-, mini- and small hydropower sites were identified through applying a more advanced methodology.[34]

Taking into account the rugged relief and heavy rainfall patterns across the many river basins of Mexico which have not yet been studied, it can be assumed with high confidence that once a systematic and exhaustive assessment of the SHP theoretical, technical, economic and environmental potential is carried out, thousands of feasible sites will be identified, and that the total potential capacity will be considerably larger than the partial estimates available up to this point. A quick analysis of conditions for SHP development in Mexico reveals that, assuming a proportional hydropower potential with China and the EU, there could be between 9,800 and 11,500 viable hydropower plants in Mexico, with the majority being SHP plants. However, Mexico had only 100 plants of all sizes in operation as of 2019.[35,36]

The benefits that hydropower can offer the population of Mexico in terms of preservation of the environment, social well-being and economic resilience are of great importance. With the useful life of a single plant often exceeding 100 years, new hydropower projects could reach millions of families in large regions for several generations. Furthermore, demand for small-scale power generation in Mexico is significant. At the end of 2016, there were approximately 1.8 million inhabitants without access to electricity in rural communities, mainly due to their dispersion in mountainous areas. A part of this population could be served by generation from RES and SHP in particular.[17] At the same time, public awareness of the potential and objective impacts of SHP development is very limited, and prone to ideological and political manipulation promoted by competing industries. Even among professionals and energy sector officials, in Mexico it is not unusual to hear opinions stating that there is no more room for hydropower development, due to its supposed negative environmental and social effects.

RENEWABLE ENERGY POLICY

The regulation of the sustainable management of energy, clean energy obligations and the efficient use of energy is carried out by SENER, which is also involved in promoting the gradual energy transition in Mexico in compliance with relevant international agreements.[24]

Long-term goals established by existing legislation to raise the share of electricity generation from clean energy, including renewable and non-renewable sources, stipulated a 25 per cent share in 2018, a 30 per cent share in 2021, 35 per cent in 2024, 43 per cent in 2030 and 50 per cent in 2050.[11] As of 2021, Mexico had fallen behind on these targets. There are no explicitly defined targets for generation from clean RES.

Currently, projections for greenhouse gas (GHG) emissions associated with fossil fuel-based electricity generation in Mexico predict an increase from 84 $MtCO_2e$ in 2020 to 99 $MtCO_2e$ in 2034. The GHG emission factor of electricity from the SEN in 2020 was 0.494 tCO_2e/MWh.[11] The key legal frameworks shaping the policies of Mexico targeting GHG reduction include the Paris Climate Agreement, signed on 22 April 2016 and committing the country to a 22 per cent reduction by 2030, relative to the 2013 levels. There are other instruments reinforcing these policies, including the National Climate Change Strategy and the Transition Strategy to Promote the Use of Cleaner Technologies and Fuels. The goals outlined by these policies include increasing the scale and efficiency of generation from hydropower through the proper management of dams, the repowering of existing turbines and an increase in the number of hydropower plants. At the same time, distributed generation is a preferable option for rural areas, households, micro- and small businesses or shops in pursuit of a socially conscious energy transition.[11]

While there is no feed-in tariff (FIT) incentive scheme for RES in Mexico, there are other forms of incentivization. These include a 100 per cent tax deduction on the purchase of machinery and equipment for generation from RES, as well as a reduction of income tax for enterprises with projects on RES research and technology development.[37] Another incentive is a minimum required proportion of clean energy for participants in MEM transactions. It was set at 5 per cent of total electricity sold at the point of consumption in 2018, 5.8 per cent in 2019, 7.4 per cent in 2020, 10.9 per cent in 2021 and 13.9 per cent in 2022.[38,39] Finally, the requirement for a generation permit is waived for plants under 500 kW capacity.

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

The main legislation and regulations related to SHP were adjusted in the Energy Reform of 2013. These include the following:

- Political Constitution of Mexico (CPEUM);
- Law of the Electric Industry (LIE);
- Law of Energy Transition (LTE);
- Law of the Federal Commission of Electricity (LCFE);
- General Law of Ecological Balance and Environmental Protection (LGEEPA);
- Law of National Waters (LAN);
- Law of the Regulatory Commission of Energy (LCRE);
- General Law on Climate Change (LGCC).

The licensing process for SHP plants includes a sequence of steps starting with the creation of an enterprise and proceeding with federal permits in the environment, culture, indigenous people, water and electricity and energy sectors. In some cases, state-level environmental authorities may be involved rather than those at the federal level. Municipal authorities are involved in the site selection process for each of the project components. Specific licences required for SHP construction include the following:

- Constitutive act of the enterprise, with a Notary Public and Fiscal authority (SAT);
- Environmental impact assessment (EIA), with SEMARNAT, which includes a preventive report, particular EIA or regional EIA, depending on the project size, as well as a report on the land use change of forested land;
- Indigenous consultation with the Secretariat of the Interior (SEGOB);
- Water authorizations, with CONAGUA, including a surface water concession, federal zone use permit and a permit to carry out hydraulic infrastructure works in waterways and federal areas;
- Study of electric installations for power plants, with CRE, including a contract for interconnections;
- Municipal construction permits, with one or more municipalities involved;
- Power generation permit, with CRE.

The duration of the licensing process is very dependent on the attributes of each project, ranging between 18 and 30 months. The process can be costly due to the various detailed studies and designs which are required.[40]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

Entities involved in the financing of SHP in Mexico include the following:

- Commercial banks;
- National development banks and programmes: Banobras, Nacional Financiera, FIRA;
- Multilateral development banks: World Bank, Inter-American Development Bank, Development Bank of Latin America and others;
- Private RES investment funds;
- Foreign export credit agencies (ECA);
- International cooperation agencies for rural RES projects;
- Equipment suppliers' credit.

Specific programmes targeting SHP development include funding by the National Council of Science and Technology (Conacyt), which issues annual calls for proposals of applied research and development projects related to the implementation of RES, emphasizing the participation of rural communities. Additionally, there is a technical cooperation agreement signed between Government entities of Mexico and China, involving the International Center on Small Hydro Power (ICSHP) of China and the National Institute of Electricity and Clean Energies (INEEL) of Mexico, as well as the Mexican Institute of Water Technology (IMTA), for a two-year programme starting in December 2020. From 2016 to 2019, IMTA led the Iberoamerican Thematic Network on Small-Scale Hydropower (REDHIDRO), which involved the participation of 19 groups from 11 countries in the region.[38]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Barriers to the development of SHP in Mexico include a variety of environmental, socio-political, regulatory, technical and financial factors:

- Environmental: a lack of a reliable national inventory of hydropower potential, unreliable official estimates and the lack of studies on integrated water resources management that incorporates SHP projects;
- Political and social: policies that favour other conventional and RES generation technologies, campaigns against SHP by pressure groups tied to competing commercial interests, a negative social perception of SHP due to lack of accurate information, insecurity in certain regions and disproportionate demands for compensation by some potential host communities;
- Regulatory: a convoluted licensing process, restrictions in regulated areas, delays in receiving indigenous

permits due to understaffing of responsible agencies, difficulties with receiving permits for development on existing infrastructure and risks associated with new upstream developments or legal challenges to ongoing or completed projects;
- Technical: the lack of accurate information on the grid as well as limited grid coverage and capacity, partial lack of specialized personnel, technical deficiencies in SHP projects at the pre-feasibility study phase and lack of domestic manufacturing capacity for SHP plant parts and equipment;
- Financial: the growing cost of the transmission service, lack of coverage and maintenance of access roads in areas with high hydropower potential, charges based on the volume of water used rather than the energy generated, lack of FITs coupled with the low electricity purchase price and a risk of further decline in prices due to auctions, demanding terms of commercial credit, lack of financing for prospection and pre-feasibility studies, difficulties in accessing GHG emissions reduction payments and the difficulty of valuation of positive externalities of SHP development.

Enablers for SHP development in Mexico can likewise be thought of in terms of the following broad categories:
- Environmental: abundant, if not rigorously quantified, potential as well the gradually declining domestic reserves of fossil fuels that Mexico highly depends on;
- Political: the imperative for achieving energy sovereignty, international and domestic commitments to GHG reductions and RES development, and the expectation of Mexican consumers of continuing low electricity prices;
- Domestic and international economy: increasing per capita consumption of electricity, unfulfilled electricity demand of certain communities and attractive export prices for electricity in the region;
- Regulatory and financial incentives: tax breaks and reductions, prioritization of grid connections for RES, ability to sell electricity directly to end users and waiver of generation permit for plants under 500 kW capacity;
- Technical: increasing incorporation of plants of intermittent generation into the grid, availability of skilled personnel in the construction and electrical power sectors and international technical cooperation agreements in the hydropower sector.

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Nicaragua

Laura Stamm, International Center on Small Hydro Power (ICSHP)

KEY FACTS

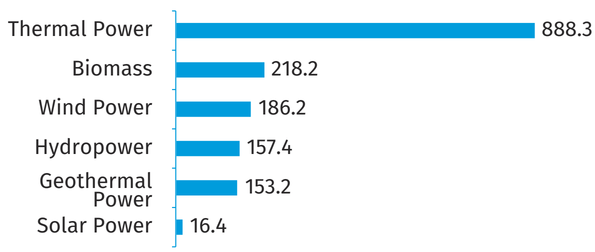
Population	6,624,554 (2020)[1]
Area	130,370 km^2 [2]
Topography	The western part of the country is characterized by valleys dissected by low rugged mountains, including the Cordillera Entre Ríos, Cordilleras Isabelia and Dariense, Huapí, Amerrique and Yolaina. In the Cordillera Entre Ríos lies the highest peak of the country, Mogotón Peak at 2,103 metres. A string of 40 volcanoes, some of which are active, stretches from north-west to south-east along the Pacific coast. The eastern part of the country consists of wide low plains reaching 100 kilometres in width.[2]
Climate	In the east of Nicaragua, the climate is slightly cooler and wetter than in the west. The Pacific side of the country has two seasons: a rainy season, lasting from May to November, and a dry season, lasting from December to April. On the Caribbean side, the dry season is from March to May, while the rainy season lasts for nine months. Annual temperatures across the country average 27 °C. However, in the northern mountains the climate is cooler with an average temperature of 18 °C.[2]
Climate Change	As global temperatures rise, the natural cycle between dry and wet seasons in Nicaragua is anticipated to become more severe, causing increases in both droughts and floods. As a result, disasters such as landslides and fires, particularly in the rural regions, are expected to become more prevalent. In addition, the water temperature of lakes and rivers has been rising and will continue to do so, which will affect water quality and thermal structure.[3]
Rain Pattern	Annual precipitation averages 1,905 mm on the Pacific side of the country and 3,810 mm on the Caribbean side.[2]
Hydrology	The central mountains of Nicaragua form the main watershed. The rivers flowing to the west of it are relatively short and drain into the Pacific Ocean or Lakes Managua and Nicaragua. The west is the region where the major lakes are located, with Lake Nicaragua being the largest lake in Central America. The most important rivers in this part of the country are the Negro, Estero Real and Tamarindo. The rivers to the east of the mountains tend to be longer and empty into the Caribbean. The main rivers here are the Coco (475 km), Río Grande de Matagalpa (430 km), Prinzapolka (254 km), San Juan (200 km), Indio (90 km), Escondido (89 km) and Maíz (60 km).[2]

ELECTRICITY SECTOR OVERVIEW

In 2020, electricity generation in Nicaragua was approximately 3,797 GWh, 71 per cent of which was sourced from renewable energy. Thermal power, primarily fuel oil and diesel, accounted for 29 per cent, geothermal power for 21 per cent, biomass for approximately 19 per cent, hydropower for just above 15 per cent, wind power for almost 15 per cent and solar power for the remaining almost 1 per cent (Figure 1).[4,5] An additional 1,071 GWh of electricity was imported, and none was exported during 2020.[6]

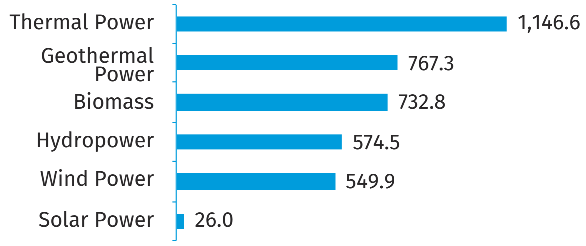
As of December 2020, the total installed capacity of Nicaragua was approximately 1,620 MW. Thermal power accounted for the majority at almost 55 per cent of the total installed capacity, biomass accounted for approximately 13 per cent, wind power for 11 per cent, geothermal power and hydropower for approximately 10 per cent each and solar power for just under 1 per cent (Figure 2).[7] Approximately 99 per cent of the total installed capacity fed the National Interconnected System, which serves the mainland, whereas the National Island System accounted for the remaining 1 per cent of capacity. While the mainland uses a mix of all of these six sources, the island system relies on just thermal power (88 per cent) and solar power (12 per cent). The total available capacity of the country's electricity system was 18 per cent lower than installed capacity, at 1,329 MW.[7]

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



Source: INE[5]

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

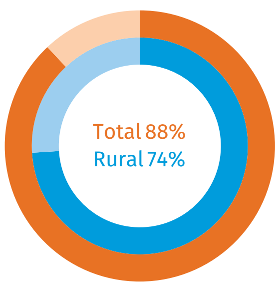


Source: INE[7]

In the 1990s, the electricity sector of Nicaragua underwent a restructuring, whereby the state-owned Nicaraguan Electricity Company (ENEL) was unbundled and partially privatized. The reform resulted in the creation of four generation companies (GEMOSA, GEOSA, HIDROGESA and GECSA), two distribution companies (DISNORTE and DISSUR) and one transmission company (ENTRESA). Two of the generation companies, HIDROGESA and GECSA, were kept public, while GEMOSA and GEOSA fully privatized. In the years since the initial breakup of ENEL, several smaller private generation companies have been established. Electricity transmission remains public, fully managed by state-owned ENTRESA. The two distribution companies were sold to the Spanish company Unión Fenosa, which originally covered the western, central and northern parts of the country, while the ENEL remained responsible for the eastern regions.[8] Since the beginning of the 2000s, however, new private distribution companies have been created and have acquired concession over many of the regions. Currently, there are 17 concessional areas of electricity distribution serviced by 14 different companies.[9]

The electricity sector is regulated by the Nicaraguan Energy Institute (INE). The National Load Dispatch Committee (CNDC) is the electricity market operator and the Ministry of Energy and Mines (MEM) oversees energy policy and planning. Electricity is traded in spot and wholesale markets, which allows the trading of electricity through long-term contracts between generating companies and distributing companies or large users.[10]

Figure 3. **Electrification Rate in Nicaragua in 2020 (%)**



Source: World Bank[12]

In recent years, the electricity sector of Nicaragua has been prioritized in national plans and initiatives such as the Rural Electrification Policy of 2005 as well as in the Sustainable Energy for All initiative of 2012. The Government has made significant efforts to improve the reliability of electricity supply as well as access in vulnerable areas.[11] The overall electrification rate in Nicaragua reached 88 per cent in 2019, with over 99 per cent in urban areas and 74 per cent in rural areas (Figure 3).[12]

Electricity tariffs vary with type, usage and distribution concession. The most common tariffs carried out by DISNORTE and DISSUR as of February 2022 are as shown in Table 1. For low-income households that use less than 150 kWh, a subsidized tariff is available.[13]

Table 1. **Electricity Tariffs in Nicaragua**

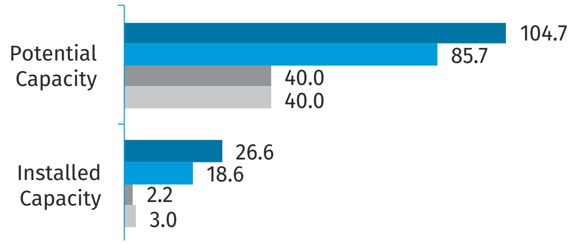
Type	*Usage*	*Cost (USD/kWh)*
Residential	*First 25 kWh*	*0.07*
	Next 25 kWh	*0.16*
	Next 50 kWh	*0.17*
	Next 50 kWh	*0.23*
	Next 350 kWh	*0.23*
	Next 500 kWh	*0.36*
	Additional above 1,000 kWh	*0.41*
Commercial	*Contracted with less than 25 kW*	*0.17*
	Contracted with more than 25 kW	*0.18*
Industrial	*Contracted with less than 25 kW*	*0.15*
	Contracted with more than 25 kW	*0.17*

Source: INE[13]

SMALL HYDROPOWER SECTOR OVERVIEW

The definition of small hydropower (SHP) in Nicaragua is up to 10 MW. The installed capacity of SHP was 26.6 MW in 2019, while the potential is estimated to be 104.7 MW, indicating that approximately 25 per cent has been developed.[14,15] Compared to the World Small Hydropower Development Report (WSHPDR) 2019, installed capacity has increased by 44 per cent, a total of 8.0 MW (Figure 4). This is a result of the completion of three additional plants: 5.70 MW San Martin, 1.48 MW Yakalwas and 0.85 MW La Camaleona. Furthermore, due to the identification of another three locations to develop SHP in the upcoming years, total potential capacity has also increased by 19 MW.

Figure 4. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in Nicaragua (MW)**



Source: MEM,[14] MEM,[15] WSHPDR 2019,[16] WSHPDR 2016,[17] WSHPDR 2013[18]

As of 2019, there were 17 operational SHP plants with a combined capacity of 26.64 MW (Table 1). There are another 20 potential sites throughout Nicaragua that are planned to be developed in the future, totaling 78.01 MW (Table 2).

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

Name	*Location*	*Capacity (MW)*
San Martin	El Tuma-La Dalia, Matagalpa	5.70
El Diamante	San Ramón Matagalpa	5.00
Salto Grande	Bonanza, North Atlantic Autonomous Region	2.80
Las Cañas	Matagalpa, Matagalpa	2.70
Siempre Viva	Bonanza, North Atlantic Autonomous Region	2.50
El Wawule	San Ramón Matagalpa	1.72
Yakalwas	Wiwili, Jinotega	1.48
El Sardinal	El Tuma La Dalia, Matagalpa	1.20
El Bote	El Cuá, Jinotega	0.96
La Camaleona	San José de Bocay, Jinotega	0.85
Bilampí-Musun	Río Blanco, Matagalpa	0.34
Tichana	Ometepe, Rivas	0.33
Kubalí-La Florida	Waslala, North Atlantic Autonomous Region	0.30
San José Bocay (Aprodelbo)	Jinotega	0.26
Las Nubes El Naranjo	Waslala, North Atlantic Autonomous Region	0.22
Rio Bravo Puerto Viejo	Waslala, North Atlantic Autonomous Region	0.18
1ro de Febrero	El Tuma, Matagalpa	0.10
Total		**26.64**

Source: MEM[14,15]

Table 2. **List of Planned Small Hydropower Projects in Nicaragua**

Name	*Location*	*Capacity (MW)*
Cuasquil	Esquipulas, Matagalpa	10.00
Santa Elisa	Matagalpa	8.70
La Esperanza	Matagalpa	7.00
Coco Torres	San Juan de Rio Coco, Madriz/ Jinotega	6.30
Quililon	El Tuma-La Dalia, Matagalpa	6.00
El Tortuguero	El Tortuguero, South Atlantic Autonomous Region	5.50
Zopilota	El Tuma-La Dalia, Matagalpa	5.10
El Ayote	Chontales y South Atlantic Autonomous Region	5.00
El Tigre	El Tuma-La Dalia, Matagalpa	5.00
Monte Cristo	San Sebastián de Yalí, Jinotega	4.00
El Mono	Jinotega	3.30
Colombina	Santa Ma de Pantasma, Jinotega	2.70
El Loro	El Tuma-La Dalia, Matagalpa	2.50
La Mora	El Tuma-La Dalia, Matagalpa	1.90
Las Canoas	Teustepe, Boaco	1.79
Salto Los Chepes	San Rafael del Sur, Managua	0.90
San Francisco	El Tuma-La Dalia, Matagalpa	0.90
Wapí-Salto Mollejones	El Rama, South Atlantic Autonomous Region	0.77
San José - El Malacate	Pantasma, Jinotega	0.42
La Unión - Salto Negro	Chontales	0.23
Total		**78.01**

Source: MEM[14,15]

RENEWABLE ENERGY POLICY

The Government of Nicaragua aims to increase the share of renewable energy sources (hydropower, wind power, solar power, biomass and geothermal power) in the energy mix. The commitment began in the early 2000s, when a series of policies and laws were first implemented. The National Energy Policy of 2004 established the policy framework for the promotion of renewable energy. In 2005, Law 532 on the Promotion of Electricity Generation with Renewable Resources declared that it is of national interest to generate electricity using renewable energy sources. The Law also provides financial incentives to encourage the establishment of renewable energy plants including exemption of import taxes, local taxes, value added taxes and income taxes for the first seven years of a new energy plant's life. It also obligates utilities to buy energy from renewable energy plants via a bidding process.[19]

Intertwining the goals to increase renewable energy as well as to increase general access to electricity, in 2005 the country released the Rural Electrification Policy, which promotes the expansion of electricity to rural areas, with special prioritization on using renewable sources.[19] To complement this policy, Law 554 on Energy Stability passed in 2005, defined measures to ensure that energy is available to all income levels, providing subsidies to residential usage of 150 kWh or less per month, and created the Fund for Energy Development and the Energy Crisis Fund, all of which prioritizes renewable energy. The law further insists that the Government should seek international funding for renewable energy generation projects.[20]

The Plan for Electricity Generation Expansion 2016–2030 provides a comprehensive set of plans and goals for the country's electricity sector. The plan outlined the expectation that by 2030, an additional 1,223 MW of new capacity will be added to the country's electricity system. This includes 138 MW of biomass, 74 MW of solar photovoltaics (PV), 143 MW of wind power, 135 MW of geothermal power, 271 MW of reservoir-based hydropower and 22 MW of run-of-river hydropower capacity. However, the plan also foresees 440 MW of new thermal power capacity, consisting of fuel oil and natural gas plants. Nonetheless, the plan's goal was to reduce the share of thermal power generation in the country's energy mix from 45 per cent in 2018 to 36 per cent in 2023 and to 27 per cent in 2030, with the remaining share being from renewable energy.[21] In 2020, the actual electricity generation in the country was 29 per cent thermal energy and 71 per cent renewable energy, demonstrating steady progress towards the 2030 goal.[5]

Among all renewable energy sources, hydropower is expected to see the greatest addition of new capacity in the coming decade according to the plan. In general, the Government has declared hydropower development to be an important part of its energy policy and a favourable legal framework and an attractive incentive structure have been established for hydropower projects up to 5 MW.[10]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

Law 476 for the Promotion of the Hydroelectric Subsector stipulates that hydropower projects below 1 MW do not need a water concession. Instead, producers can obtain a permit for a period of 15 years. For plants with capacities of 1–5 MW, a simplified procedure applies for obtaining a water concession from the Ministry of Development, Industry and Trade. Additionally, Law 217 for the Protection of Environment and Natural Resources stipulates that projects with capacities below 5 MW do not need an environmental impact assessment.[10]

COST OF SMALL HYDROPOWER DEVELOPMENT

The costs associated with the development of SHP plants in Nicaragua are site-specific and depend on various factors. The total costs of three hydropower projects that were completed in 2018 are shown in Table 3.

Table 3. **Costs of Selected Small Hydropower Projects in Nicaragua**

Name	*Capacity (MW)*	*Total cost (USD million)*	*Cost per MW (USD million/MW)*
San Martin	5.70	19.4	3.4
Yakalwas	1.48	7.5	5.0
La Camaleona	0.85	3.8	4.4

Source: MEM[15]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

SHP development in Nicaragua is mainly financed by private investors, international firms, or international organizations such as the European Investment Bank, the Inter-American Investment Bank and the Central American Bank for Economic Integration. The county's investment promotion agency, PRONicaragua, is an integral part of foreign direct investment and facilitates the process with potential investors.[22]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

The Plan for Electricity Generation Expansion 2016–2030 expresses concern for the effects of climate change on the country's hydropower. Due to the increased prevalence of droughts expected by 2030, the contribution of natural water resources to hydropower plants may decrease by up to 13 per cent. This decrease in input could possibly result in an up to 30 per cent decrease in power generation.[21]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Barriers hindering the development of SHP in Nicaragua include:

- Difficulty in accessing funding because of the high initial cost of projects. Commercial finance is needed over the long-term, but, in general, financial assistance is short-term with high interest rates;
- The duration of power purchase agreements is too short to motivate SHP project development. Therefore, it is difficult to make long-term investment decisions;

- The approved fiscal incentives for hydropower projects do not create a level playing field for hydropower development compared to thermal power projects, since the latter continue to be highly subsidized;
- Lack of experience and technological knowledge in the implementation of SHP plants.[10,17]

Enablers encouraging the development of SHP in Nicaragua include:

- Strong presence of political will and dedication to the transition to renewable energy and climate action;
- Very limited restrictions to foreign direct investment in the energy sector;
- Between lakes, lagoons and rivers, the country's surface area is 10 per cent water, offering great possibilities to explore for more potential hydropower sites;
- It has been estimated that there is approximately 3,760 MW of total potential of hydropower generation throughout the country given a 100 per cent plant availability scenario, larger than any other renewable resource in the country. Currently less than 5 per cent of that is being utilized leaving an abundance of untapped potential;
- As rural electrification is underway, electricity demand is expected to increase accordingly.[10,22]

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Panama

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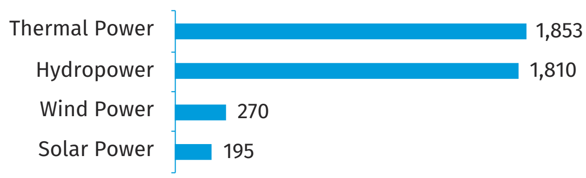
KEY FACTS

Population	4,218,808 (2019)[1]
Area	75,420 km^2 [2]
Topography	There are rugged mountains to the west and towards the Caribbean Sea and rolling hills and vast plains by the Pacific Coast. The lowlands cover approximately 70 per cent of the country's territory. The highest point in Panama is the Volcán Barú, which rises to 3,475 metres above sea level.[2]
Climate	Panama has a tropical climate with two seasons, dry and rainy. The variations in climatic conditions depend on the region and the altitude. Winter is the wet season and lasts from May to November, while summer is the dry season and lasts from December to April, with March and April ordinarily being the warmest months. The annual average temperature in Panama ranges between 23 °C and 27 °C for the coastal areas and in the interior, while at higher altitudes it can drop to 19 °C. In general, temperatures are reflective of the country's tropical climate profile and increase 0.56 °C for every 100 metres of altitude. [3]
Climate Change	Observed climate change impacts in Panama have included intense rains during the dry season, long periods of drought and sea level rise. Increased energy demand driven by rising temperatures has also been observed. The projected climate change impacts by the end of the 21st century include loss of crops and soils, loss of the coastline as a result of storm surges, as well as more severe flooding in large urban centres, with damage to infrastructure and services.[4]
Rain Pattern	Panama has a yearly average precipitation of 2,928 mm. The Pacific region shows a wet season pattern from May to November. For the Atlantic region, precipitation is continuous throughout the year.[5,6]
Hydrology	There are approximately 500 rivers in Panama in 52 watersheds. Seventy per cent of the rivers, including most of the longer streams, run to the Pacific coast, while 30 per cent run to the Atlantic coast.[7]

ELECTRICITY SECTOR OVERVIEW

The total installed electricity capacity of Panama was 4,128 MW in 2020, representing a 26 per cent increase since 2017. Thermal power plants provided 1,853 MW (45 per cent) of the total, hydropower provided 1,810 MW (44 per cent), wind power provided 270 MW (7 per cent) and solar power provided 195 MW (5 per cent) (Figure 1).[8]

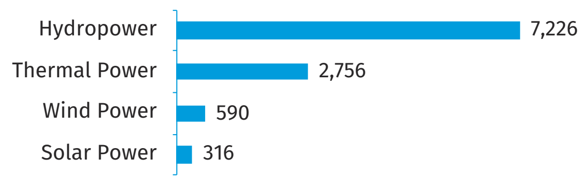
Figure 1. **Installed Electricity Capacity by Source in Panama in 2020 (MW)**



Source: ASEP[8]

Annual generation of electricity in Panama in 2020 amounted to approximately 10,887 GWh. Hydropower accounted for 7,226 GWh (66 per cent) of the total, thermal power accounted for 2,756 GWh (25 per cent), wind power accounted for 590 GWh (5 per cent) and solar power accounted for 316 GWh (3 per cent) (Figure 2). Renewable energy sources (RES) thus accounted for 74 per cent of all electricity generation in the country in 2020. Exports of electricity in 2020 amounted to 524 GWh, while imports were 86 GWh.[8]

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

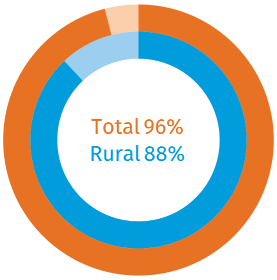


Source: ASEP[8]

Note: Values were calculated based on percentages quoted in the source.

The nationwide rate of electricity access in Panama was nearly 96 per cent in 2019 and 88 per cent in rural areas (Figure 3).[9] Electricity consumption in 2020 amounted to 9,521 GWh and an additional 125 GWh were accounted for by self-consumption.[10]

Figure 3. **Electrification Rate in Panama in 2019 (%)**



Source: World Bank[9]

The National Secretariat of Energy, established by Law 43 on 23 April 2018, is responsible for overseeing the energy sector in Panama.[11] The Rural Electrification Office (OER), operating under the supervision of the Ministry of Public Works, is tasked with providing energy to rural, isolated areas not connected to the national grid. The OER works to increase electricity access in rural areas both by extending electrical networks as well as by developing local generating capacity through projects employing RES, including small hydropower (SHP).[12,13]

Key legislation regulating the energy sector in Panama includes Law No. 6 introduced on 3 February 1997 (and its later amendments) as well as Decree Law No. 22 of 1998.[11,14,15,16] Following the privatization of the public electricity utility in 1998, the Electric Transmission Company (ETESA), a public limited company, was put in charge of the transmission and distribution of electricity. ETESA is additionally responsible for grid expansion planning, construction of new transmission and distribution lines and grid maintenance.[17] The remuneration for the services carried out by ETESA is likewise regulated by Law No. 6 of 1997.[14]

The electricity grid of Panama consists of three main transmission lines, all located along the Pacific coast. All three lines are complete, fully operational and operating at full capacity.[17] Targets for the ongoing and future expansion of the electricity grid are outlined in the National Interconnected System Expansion Plan 2019–2033. The Plan consists of three major documents:

- Basic studies including forecasts of energy demand and power at the level of the Main Transmission System;
- The Indicative Generation Plan, the objective of which is to provide information on the expansion of generation capacities and the evolution of the generation sector, as well as to provide an analysis of the current supply situation and potential energy alternatives, taking into account multiple variables including energy demand and resources, hydrology, and availability and costs of fuels, among others;
- The Expansion Plan of the Transmission System, which will become mandatory once approved by the National Public Service Authority (ASEP).[18]

Additionally, Panama is developing interconnection strategies with neighbouring countries in Central America through the Central American Electric Interconnection System (SIEPAC). This system was officially inaugurated in December 2014 and includes Guatemala, Honduras, Nicaragua, El Salvador, Costa Rica and Panama. With an investment of USD 500 million USD, the system consists of one line of 230 kV connected to capacities of 300 MW. This initiative has great potential, although exchanges have been very modest so far. A separate integration plan with Colombia has also been proposed, which is expected to produce price advantages and involves the introduction of a virtual generator with a capacity of 400 MW.[19,20]

The largest independent electricity producers in Panama as of 2020 were Minera Panama mining company with an installed capacity of 300 MW and the Panama Canal Authority with an installed capacity of 213 MW, 72 per cent of which was provided by thermal power plants and 28 per cent by hydropower plants.[8,21]

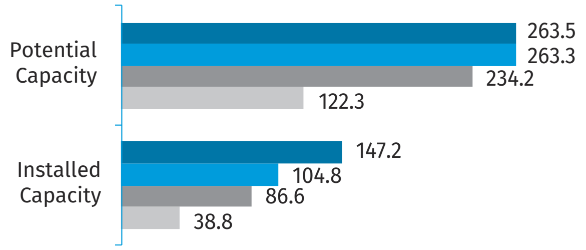
Electricity tariffs in Panama are set on a monthly basis by the ASEP and include a variable price that fluctuates with the fuel market prices. From 2016 to 2021, the average electricity tariff in Panama fluctuated between 0.163 USD/kWh to 0.217 USD/kWh before subsidies. Subsidized electricity tariffs have ranged from a low of 0.149 USD/kWh in December 2020 to a high of 0.187 USD/kWh in December 2019.[22]

SMALL HYDROPOWER SECTOR OVERVIEW

The Latin American Energy Organization (OLADE) defines SHP plants as hydropower plants with a capacity of up to 5 MW, while the legal framework of Panama provides incentives for hydropower plants up to 20 MW.[23,24] However, for the sake of comparison with previous editions of the World Small Hydropower Development Report (WSHPDR), the current report uses the up to 10 MW definition for SHP.

The total installed SHP capacity up to 10 MW in Panama was 147.2 MW as of March 2021, provided by 24 SHP plants, while an additional 116.2 MW were available in the form of ongoing and planned SHP projects as well as potential SHP sites.[25,26] The total SHP potential capacity of the country is thus estimated at nearly 263.5 MW. Relative to the WSHPDR 2019, installed SHP capacity in the country has increased by 40 per cent due to the construction of several new SHP plants. Potential capacity has meanwhile remained virtually unchanged, as ongoing development has included previously-identified potential sites. (Figure 4).[27] A partial list of existing SHP plants is provided in Table 1.

Figure 4. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in Panama (MW)**



Source: ASEP,[25,26] WSHPDR 2019,[27] WSHPDR 2013,[28] WSHPDR 2016[29]

Table 1. **List of Selected Existing Small Hydropower Plants in Panama**

Name	*Location*	*Capacity (MW)*	*Plant type*	*Operator*	*Launch year*
San Andrés	Chiriquí	10.00	N/A	Desarrollos Hidroeléctricos Corp.	2021
Bajos del Toluma	Chiriquí	6.30	Run-of-river	Hidroeléctrica Bajos el Toluma, S.A.	2018
La Cuchilla	Chiriquí	7.62	Run-of-river	Hidro Piedra, S.A.	2018
Bugaba 2	Chiriquí	5.86	Run-of-river	Empresa Nacional de Energía, S.A. (ENADESA)	2016
Las Cruces	Veraguas	9.38	Run-of-river	Corporación de Energía del Istmo Ltda, S.A. (CEISA)	2015
Bugaba I	Chiriquí	3.29	Run-of-river	Empresa Nacional de Energía, S.A.	2014
San Lorenzo	Chiriquí	8.70	Run-of-river	Hidroeléctrica San Lorenzo, S.A.	2014
Perlas Norte	Chiriquí	10.00	Run-of-river	Las Perlas Norte, S.A.	2013
Perlas Sur	Chiriquí	10.00	Run-of-river	Las Perlas Sur, S.A.	2013
Mendre 2	Chiriquí	8.12	Run-of-river	Electrogeneradora del Istmo, S.A.	2013
El Fraile	Coclé	5.31	Run-of-river	Hidroibérica, S.A.	2012
Los Planetas I	Chiriquí	4.75	Run-of-river	Saltos del Francoli, S.A.	2011
Macano	Chiriquí	5.80	Run-of-river	Hidro Boquerón, S.A.	2010
Paso Ancho	Chiriquí Viejo	6.00	N/A	Paso Ancho Hydro Power Corp.	2010
Los Algarrobos	Chiriquí	9.86	Reservoir	Empresa de Energía y Servicios, S.	2009
Antón III	Coclé	1.40	Reservoir	Hydro Panamá, S.A.	2009
Concepción	Chiriquí	10.00	Reservoir	Isthmus Hydro Power, Corp.	2008
Candela I	Chiriquí	0.53	Reservoir	Café de Eleta, S.A.	2006
Antón II	Coclé	1.40	Reservoir	Hydro Panamá, S.A.	2003
Dolega	Chiriquí	3.12	Reservoir	Empresa de Energía y Servicios, S.A.	2001

Source: ASEP[25]

There was a total of nine SHP projects in various stages of development in Panama as of 2021, with a planned capacity of 52.4 MW.[26] However, many of them are currently suspended, with the proposed launch dates no longer relevant. Several of the ongoing projects are listed in Table 2.

Table 2. **List of Selected Ongoing Small Hydropower Projects in Panama**

Name	*Location*	*Capacity (MW)*	*Developer*	*Planned launch year*	*Development stage*
Chuspa	Chiriquí, Boquerón, Paraiso y Guayabal	10.00	Navitas International, S.A.	2020	Under construction
Colorado	Chiriquí, Bugaba, Volcán	5.14	Hidroeléctrica Barriles, S.A.	2017	Final Design, Pending of Approval
India Vieja	Chiriquí, Boquete, Caldera	2.00	Darrin Business, S.A.	2017	Construction Hold
Terra 4-Tizingal	Chiriquí, Renacimiento, Montelirio	4.50	Hidroeléctrica Tizingal, S.A.	2017	Final Design
Rio Piedra	Colón, Portobelo, Portobelo	9.00	Hidroelectrica Río Piedra, S.A.	2015	Design; Environmental Impact Assessment study under review

Source: ASEP[26]

Additionally, 13 sites were considered potential prospects for SHP development, with a total potential capacity of 63.9 MW.[26] Several sites are provided in Table 3.

Table 3. **List of Selected Potential Small Hydropower Sites in Panama**

Name	*Location*	*Potential capacity (MW)*
El Recodo	Boca del Monte, San Lorenzo, Chiriquí	9.94
Gariche 2-3	San Andrés, Bugaba, Chiriquí	9.60
Chiriquí	Caldera, Boquete, Chiriquí	7.92
Caña Blanca	Los Ángeles, Gualaca, Chiriquí	7.85
Gariche	Volcán, Bugaba, Chiriquí	6.47

Source: ASEP[26]

RENEWABLE ENERGY POLICY

Panama has committed to achieving Sustainable Development Goal (SDG) 7 through promoting an energy transition policy and electric mobility. Likewise, Panama ratified the Paris Climate Change Agreement (PCCA) in September 2016, committing itself to reducing greenhouse gas (GHG) emissions.[30] The National Determined Contribution (NDC) of Panama set a target of increasing electricity generation from RES by 30 per cent by the end of 2050, relative to 2014. In 2020, Panama presented an updated NDC, which included targets of an 11.5 per cent emissions reduction by 2030 and a 24 per cent reduction by 2050, relative to the trend under the business-as-usual scenario.[31]

In addition to international agreements on GHG reductions and sustainable development, the commitment of Panama to RES development is motivated by rising electricity demand and the high cost of electricity in the country. In April 2011, Law No. 44 was adopted with the aim of promoting various forms of RES with a particular focus on wind power. The law provides for the application of long-range modelling of alternative energy development strategies in a variety of possible combinations. The Law was further developed with the passage of Law No. 18 in March 2013.[15,32]

The COVID-19 pandemic has contributed to delays in the implementation of ongoing projects and the development of new projects in the electricity sector, resulting in a negative impact on the national electricity market. Two new regulations, MIPRE-2020-0015448 and its modification MIPRE-2021-002034, were adopted between 2020 and 2021 to address this issue and guarantee the security of the electricity supply by outlining measures for short-term contracting of power and energy.[33,34]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

Along with promoting other RES, Law No. 45-2004 established incentives for SHP projects of up to 20 MW capacity. These include:

- SHP plants up to 10 MW are allowed to sell generated electricity both directly and indirectly;
- SHP projects between 10 MW and 20 MW are exempt from paying import taxes and levies on the first delivered 10 MW for 10 years, including the Tax on the Transfer of Personal Property and Provision of Services for the importation of equipment, machinery, materials and spare parts;
- SHP projects up to 10 MW can qualify for a subsidy of the original investment costs of up to 25 per cent, calculated in terms of a reduction of equivalent tons of CO_2 emissions per year, as well as a tax exemption of up to 5 per cent of the total value of direct investment in connected infrastructure to be transferred to public ownership (roads, bridges, sewer lines, etc.).[24]

COST OF SMALL HYDROPOWER DEVELOPMENT

SHP development in Panama relies primarily on the private sector. The construction cost of the 4.95 MW Los Planetas-1 SHP plant in Chiriqui province was USD 21.3 million, or 4,303 USD/kW.[35] Meanwhile, the estimated value of the 6.3 MW Bajos de Toluma SHP plant was USD 22.4 million in 2017, or 3,556 USD/kW.[36]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Although there is a favourable legal framework in Panama granting fiscal incentives to SHP plants, development of the SHP sector is not significant.

The most important barrier to SHP development in the country is the lack of interest from private finance in supporting investment in SHP. As a result, rural communities are almost exclusively dependent on state financing for electricity sector development, including SHP.

Factors enabling SHP development in the country include:

- A solidly established hydropower sector with many operational SHP plants, most constructed in the last few decades;
- Fiscal incentives in the form of tax exemptions provided for SHP;
- Existing SHP projects that have stalled at various stages of implementation and may welcome additional financing;
- An abundance of identified prospective sites for new SHP development.

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