UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

World Small Hydropower Development Report 2019

Americas

Disclaimer

The *World Small Hydropower Development Report 2019* is jointly produced by the United Nations Industrial Development Organization (UNIDO) and the International Center on Small Hydro Power (ICSHP) to provide development information about small hydropower.

The opinions, statistical data and estimates contained in signed articles are the responsibility of the authors and should not necessarily be considered as reflecting the views or bearing the endorsement of UNIDO or ICSHP. Although great care has been taken to maintain the accuracy of information herein, neither UNIDO, its Member States nor ICSHP assume any responsibility for consequences that may arise from the use of the material.

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as 'developed', 'industrialized' and 'developing' are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

Suggested citation:

LIU, D., LIU, H., WANG, X., and Kremere, E., eds. (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www. smallhydroworld.org.

ISSN: 2406-4580 (print)
ISSN: 2706-7599 (online)

The digital copy is available on www.smallhydroworld.org.

Design: red not 'n' cool
Cover Picture: gregbrave / 123rf.com

World Small Hydropower Development Report 2019

AMERICAS

Acknowledgements

The World Small Hydropower Development Report 2019 was prepared under the overall guidance of Tareq Emtairah, Director of the Department of Energy at the United Nations Industrial Development Organization (UNIDO) and LIU Deyou, Director General of the International Center on Small Hydro Power (ICSHP).

The Report was headed by LIU Heng, Senior Technical Expert at UNIDO and consulted by HU Xiaobo, Chief of the Division of Multilateral Development at ICSHP. This lengthy, and at times, arduous endeavour was coordinated by Eva Krēmere at UNIDO and WANG Xianlai at ICSHP. The Report is the result of three years of intense research efforts and was backed by a talented and indispensable team of researchers at ICSHP and a vast number of experts in the field of small hydropower.

***WSHPDR 2019* team:**

Head	LIU Heng - Senior Technical Advisor, United Nations Industrial Development Organization (UNIDO)
Coordinators	Eva Krēmere - United Nations Industrial Development Organization (UNIDO) WANG Xianlai - International Center on Small Hydro Power (ICSHP)
Communications	Eva Krēmere - United Nations Industrial Development Organization (UNIDO) Oxana Lopatina - International Center on Small Hydro Power (ICSHP)
Team	UNIDO: Eva Krēmere, Sanja Komadina. Interns: Eleanor Vickery, Steven Moser ICSHP: HU Xiaobo, WANG Xianlai, Oxana Lopatina, Ofelia Raluca Stroe, Alicia Chen Luo, Clara Longhi, Georgii Nikolaenko, Riona Lesslar

The invaluable contributions and insightful comments received greatly enhanced the overall quality of the Report:

Advisory Board	Alfonso Blanco Bonilla, Latin American Energy Organization (OLADE); Linda Church-Ciocci, National Hydropower Association (NHA); Dirk Hendricks; European Renewable Energies Federation (EREF); Eddy Moors, IHE Delft Institute for Water Education; Richard Taylor, International Hydropower Association (IHA); Adrian Whiteman, International Renewable Energy Agency (IRENA).
Peer Reviewers	Andrew Blakers, Johannes Geert Grijsen, Sergio Armando Trelles Jasso, Furkat Kadyrov, Wim Jonker Klunne, Galina Livingstone, Miroslav Marence, Niels Nielsen, Michael Panagiotopoulos, Mathis Rogner, Wilson Sierra.
Regional Authors	Engku Ahmad Azrulhisham, Guillaume Binet, Edilbek Bogombaev, Paulo Alexandre Diogo, Pirran Driver, José Fábrega, Cleber Romao Grisi, Richard Hendriks, Michela Izzo, Bryan Karney, Egidijus Kasiulis, Wim Jonker Klunne, Arun Kumar, Miroslav Marence, Niels Nielsen, Daniel Paco, Alberto Sánchez, Mohamedain E. Seif Elnasr, Stafford W. Sheehan, Janusz Steller, Phillip Stovold.

Authors and Contributors

Fagan Abdurahmanov, Donald Adgidzi, Leonardo Aburto, Clément Bill Akouèdénoudjè, Loboso Cosmas Manase Akwenya, Sameer Sadoon Algburi, Mohammad Hassan AlZoubi, Gabrial Anandarajah, Viktor Andonov, Darlene Arguelles, Vicky Ariyanti, Fredrik Arnesen, John Kobbina Arthur, Aleksandra Aubreht, Engku Ahmad Azrulhisham, Betsy Bandy, Bohuslav Barta, Batdelger Batsuuri, Alexis Baúles, Madhu Prasad Bhetuwal, Sow Aissatou Billy, Andrew Blakers, Alaeddin Bobat, Thomas Buchsbaum-Regner, Nebiyu Bogale, Alfredo Samaniego Burneo, Ejaz Hussain Butt, Abou Kawass Camara, Sonya Chaoui, Marco Antonio Jimenez Chavez, Piseth Chea, Chi Chen, Gift Chiwayula, Brenda Chizinga, Nouri Chtourou, Edchilson Cravid, Manana Dadiani, Denise Delvalle, Jovan Despotović, Johanna D'Hernoncourt, Sinalou Diawiara, Camille Augustin Kabasele Dikangala, Fikru Gebre Dikumbab, Paulo Alexandre Diogo, Jonas Dobias, Aurélie Dousset, Choten Duba, Khalil Elahee, Azubike Emechebe, Lambert Engwanda, Haider Khalil Essa, José Fábrega, Giovanna Fantin, Nimashi Fernando, Soukaina Fersi, Geraldo Lúcio Tiago Filho, Sione Foliaki, , Danilo Fras, Fombong Matty Fru, Tokihiko Fujimoto, Patrick Furrer, Garaio Gafiye, Camila Galhardo, Morella Carolina Gilarias, Gaelle Gilboire, Florence Gimbo, Carlos González, Cleber Romao

Grisi, Leo Guerrero, Mathias Gustavsson, Mohammad Hajilari, Nihad Harbas, Eoin Heaney, Samira Heidari, Richard Hendriks, Sven Homscheid-Carstens, Arian Hoxha, Maria Ibragimova, Helvi Ileka, Michela Izzo, Frantisek Janicek, Sergio Armando Trelles Jasso, Rim Jemli, Kurt Johnson, Morsha Johnson-Francis, Furkat Kadyrov, J.K. Kaldellis, Rachel Kalebbo, Papias Karanganwa, Bryan Karney, Raúl Pablo Karpowicz, Egidijus Kasiulis, Shorai Kavu, Fredrick Kazungu, Sahib Khalilov, Eva, Kremere, Maris Klavins, Daniel Klinck, Juliet F. Khosrowabadi Kotyk, Dong Hyun Kim, Wim Jonker Klunne, John Korinihona, Arun Kumar, Sarah Acholla Kwach, Mohamed-Yahya Ould Lafdal, Gianluca Lazzaro, Seung Oh Lee, Disashi Nyama Lemba, Jean-Marc Levy, Patricia Lewin, Robert Limoko, Galina Livingstone, Frank Lucas, Esménio Isabel João Macassa, Manuel Mahler-Hutter, Sarmad Nozad Mahmood, Ewa Malicka, Igor Malidzan, Pedro Manso, Ghulam Mohd Malikyar, Sharon Mandair, Luis Manzano, Miroslav Marence, Cayetano Espejo Marín, Ramón Garcia Marín, Rupeni Mario, Anare Matakiviti, Juan José García Méndez, Sierra Method, Luiza Fortes Miranda, Ditiro Benson Moalafhi, Conrado Moreno, Bastian Morvan, Carine Mukashyaka, Reynolds Mukuka, Jaime Muñoz, Wakati Ramadhani Mwaruka, Sandar Myo, Thet Myo, Anna Nadolny, Bilal Abdullah Nasir, N'guessan Pacôme N'Cho, Jami Nelson-Nuñez, Leonel Wagner Neto, Desire Florentin Ngaibona, Peter Norville, Robert Nyamvumba, Abdeen Mustafa Omer, Emna Omri, Karim Osseiran, Sok Oudam, Victor Owuor, Daniel Paco, Domingos Mosquito Patrício, Cláudio Moisés Paulo, Elsia Paz, Henrik Personn, Pihla Pietilainen, Vlad Florin Pîrăianu, Adelino Sousa Pontes, Nuwan Premadasa, Thoeung Puthearum, Peeter Raesaar, Carlos Fernando Moros Ramirez, Laura Lizano Ramon, Karin Reiss, Jorge Reyes, Tsiky Harivelo Robison, António Carmona Rodrigues, Mathis Rogner, João Russo, Vladimir Russo, Jorge Saaverda, Soussou Sambou, Alberto Sánchez, Saso Santl, Karine Sargsyan, Vahan Sargsyan, Martin Scarone, Öztürk Selvitop, Jorge Servert, Shamsuddin Shahid, Davit Sharikadze, Mahender Sharma, Stafford W. Sheehan, M. Hady Sherif, Manish Shrestha, Sangam Shrestha, Mundia Simainga, Martin Sinjala, Jeremie Sinzinkayo, Seming Skau, Nicolae Soloviov, Paradis Someth, Amine Boudghene Stambouli, Phillip Stovold, Samiha Tahseen, Ibrahim Ragab Mohamed Teaima, Pierre Kenol Thys, Anastasiya Timashenok, Mikael Togeby, Ernesto Torres, Philbert Tuyisenge, Alexander Urbanovich, Katalin Varga, Petro Vas'ko, Akhomdeth Vongsay, Harsha Wickramasinghe, Horace Williams, Mark Williams, Kassius Klei Ximenes, Rabiou Hassane Yari.

2.1 Caribbean

Alberto Sánchez, GEF Small Grants Programme (SGP/GEF/UNDP); Michela Izzo, Guakía Ambiente

Introduction to the region

The Caribbean region is bordered by the United States to the north, Mexico and Central America to the west, South America to the south and the Atlantic Ocean to the east. The region includes 28 countries and territories. Ten of these will be covered in this report: Cuba, Dominica, the Dominican Republic, Grenada, Guadeloupe, Haiti, Jamaica, Puerto Rico, Saint Vincent and the Grenadines and Saint Lucia. The climate of the region can vary from arid (less than 400 mm of annual rainfall) to extremely humid (more than 7,000 mm). The highest humidity is seen in areas exposed to the trade winds. The Antilles show a very complex topography, highly influenced by the active regional tectonics. For this reason, altitude is significantly variable, ranging from less than –40 metres to more than 3,000 metres above sea level. The Greater Antilles (Cuba, the Dominican Republic, Jamaica and Puerto Rico) are home to the largest rivers and hydropower potential. According to country-specific data, the total installed capacity of the region is 18.1 GW, of which less than 5 per cent (898 MW) is from hydropower and less than 1 per cent (176 MW) from small hydropower (SHP). An overview of the countries in the Caribbean is presented in Table 1.

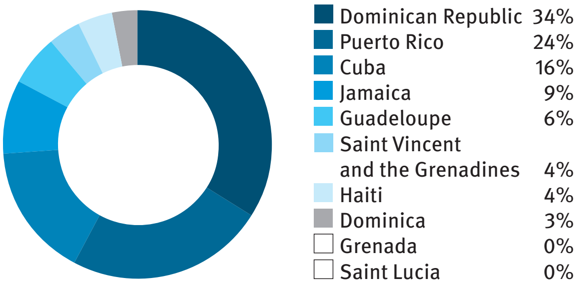
Electricity access normally exceeds 95 per cent, with Cuba and Dominica providing their entire populations with electricity. The electrification rate of Puerto Rico was previously at 100 per cent as well, however, the distribution network was destroyed in the summer of 2017 by Hurricane Maria and has not yet been fully restored. The only country in the region with a low electrification rate is Haiti, where economic and institutional conditions are highly critical and only 39 per cent of the population have access to electricity, which is, however, also not continuously provided. In the Dominican Republic, access to electricity in rural areas still remains a challenge, with 9 per cent of rural population not having access to this service yet, especially in the most vulnerable and isolated communities. The countries with the highest percentages of the population without access to electricity also tend to face such problems as low efficiency and high electricity losses.

The region is characterized by quite high domestic electricity rates, which exceed 0.25 US$/kWh in Saint Lucia (0.28 US$/kWh). Jamaica has the lowest rate (0.08 US$/kWh) for consumption less than 100 kWh. The average value in the region is 0.18 US$/kWh. Nevertheless, a reduction of electricity rates has been noted during the last three years.

The 10 countries and territories of the region covered in the present report highly depend on imported fossil fuels for electricity generation. In the majority of these countries, electricity (generation, transmission, distribution and commercialization) is monopolistically managed, even though some changes have occurred in recent years to bring about the entrance of other participants into the market.

The Dominican Republic, Puerto Rico, Jamaica and Cuba account for more than 80 per cent of the regional share of installed SHP (Figure 1). Between the *World Small Hydropower Development Report* (*WSHPDR*) *2016* and *WSHPDR 2019*, the installed SHP capacity has increased by 3 per cent from 171.5 MW to 176.7 MW. This increase has been particularly linked to the new capacities introduced in Cuba and the Dominican Republic (Figure 3). The net increase in the installed capacity in the region was, however, diminished by the decreased capacity of Jamaica due to the extension of one of its hydropower plants, which brought it beyond the 10 MW threshold.

Figure 1.
Share of regional installed capacity of small hydropower up to 10 MW by country in the Caribbean



Source: *WSHPDR 2019* [5]

Note: The use of the term 'country' does not imply an opinion on the legal status of any country or territory.

Table 1.
Overview of countries in the Caribbean

Country	*Total population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Cuba	11.5	23	100	6,407	20,459	66	64
Dominica	0.07	30	100	27	112	7	36
Dominican Republic	10.6	20	99	3,460	15,892	616	1,510
Grenada	0.1	64	92	51	223	0	0
Guadeloupe	0.4	2	N/A	573	1,791	11	34
Haiti	11.0	46	39	349	1,089	61	131
Jamaica	2.7	45	98	941	4,363	30	157
Puerto Rico	3.7	6	85	6,161	16,372	100	51
Saint Lucia	0.2	81	98	91	400	0	0
Saint Vincent and the Grenadines	0.1	48	97	58	166	7	37
Total	**40.4**	-	-	**18,118**	**60,867**	**898**	**2,020**

Source: *WSHPDR 2016*,[2] *WSHPDR 2019*,[3] WB,[4] WB[5]

Small hydropower definition

The countries of the region that have an official definition of SHP define it to be up to 10 MW of installed capacity. Cuba, Grenada and Saint Lucia do not have an official definition (Table 2).

Regional small hydropower overview and renewable energy policy

All countries in the region are dealing with high costs and environmental problems linked to fossil fuels, with electricity generation being one of the most impacted sectors.

For this reason, all of the countries covered in this section have begun to promote the use of renewable energy sources, which are specifically mentioned in National Energy Policies and Energy Action Plans. Some countries (Grenada, Guadeloupe, Saint Lucia, Jamaica, Puerto Rico and the Dominican Republic) have established specific goals in terms of changing the national energy mixes. Guadeloupe has one of the most ambitious targets, aiming to achieve 50 per cent of primary energy from renewable energy sources by 2030.

Among renewable energy sources, SHP systems constitute a feasible and attractive solution only in some of the countries in the region. In some cases, countries aim to continue to develop hydropower generation, also at a regional scale. For example, Dominica is focused on the development of common projects with Martinique and Guadeloupe. However, most other countries are focused on other renewable sources, especially solar and geothermal power.

Considering the fact that the region is exposed to extreme weather and climatic events, special care must be taken to develop projects based on climate change adaptation and resilience strategies.[6,7] Hurricanes are a major threat in the region. For example, Hurricane Maria caused huge damages in 2017, as well as a long interruption of electricity services for more than 90 per cent of the region's population. On the other hand, droughts, especially associated with El Niño episodes, are also an issue of major concern, especially for hydropower generation. Droughts have caused huge impacts during the recent years, and are projected to severely affect the region in the future. For this reason, specific solutions must be implemented to reduce the risk of a lack of production for SHP systems. Another aspect that must be considered is the competing use of water resources in an environment where they are increasingly limited.

With 176 MW of installed capacity, SHP accounts for 20 per cent of the total installed hydropower capacity. The region's known SHP potential is estimated at 297 MW, of which approximately 60 per cent has already been developed (Figure 2).

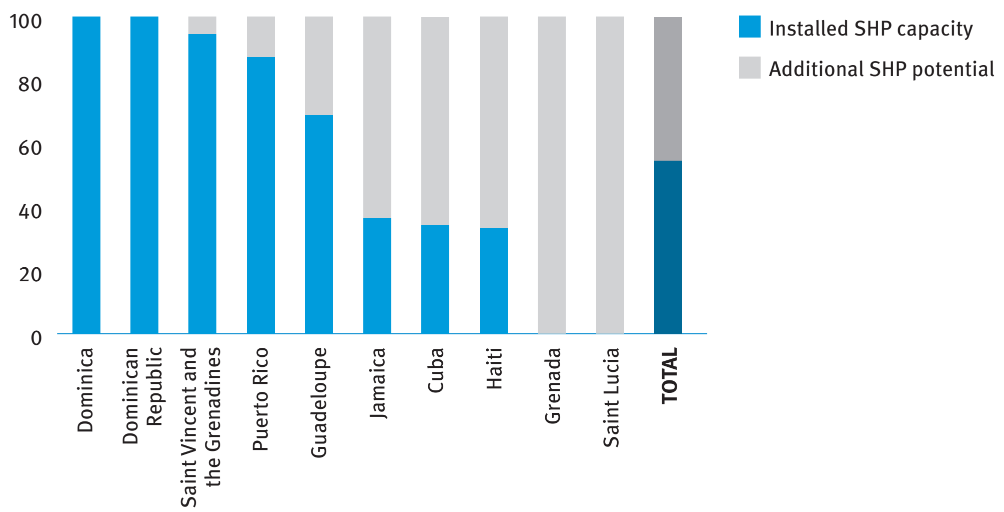
Table 2.
Small hydropower capacities in the Caribbean (local and ICSHP definition) (MW)

Country	*Local SHP definition*	*Installed capacity*	*Potential capacity*
Cuba	-	28.9	84.9
Dominica	up to 10	4.8	4.8
Dominican Republic	up to 10	59.3	59.3
Grenada	-	0	7.0
Guadeloupe	up to 10	11.1	16.1
Haiti	up to 10	7.0	20.9
Jamaica	up to 10	16.6	45.5
Puerto Rico	up to 10	41.8	47.9
Saint Lucia	-	0	2.7
Saint Vincent and the Grenadines	up to 10	7.0	7.4
Total		**177**	**297**

Source: *WSHPDR 2019* [3]

Note: The table illustrates data for local SHP definitions or the definition up to 10 MW in case of the absence of an official local one.

Figure 2.
Utilized small hydropower potential by country in the Caribbean (local SHP definition) (%)



Source: *WSHPDR 2019* [3]

Note: This Figure illustrates data for local SHP definitions or the definition up to 10 MW in case of the absence of an official local one. For Dominica and the Dominican Republic, additional potential is not known.

An overview of SHP in the countries of the Caribbean region is outlined below. The information used in this section is extracted from the country profiles, which provide detailed information on SHP capacity and potential, among other energy-related information.

With 161 SHP plants with a combined capacity of 28.9 MW, **Cuba** accounts for 15 per cent of the region's installed SHP capacity. Its total potential remains unknown. However, based on the planned projects, it is possible to conclude that there is at least 56 MW of undeveloped potential, indicating that approximately 34 per cent of the known SHP potential has been developed. The construction of these plants has been initiated by the Government and will include the conversion of existing dams and water channels for hydropower generation.

The installed capacity of SHP in **Dominica** is estimated at 4.8 MW. Previously, the country had three SHP plants – Laudat, Trafalgar and Padu. However, Hurricane Maria severely affected the entire country, including existing hydropower facilities. The Padu hydropower plant was destroyed and as of the end of 2018 remained non-operational. The Trafalgar plant experienced minor damages to the building structure, while the Laudat plant remained intact. The country's SHP potential remains unknown.

The Dominican Republic has 16 state-owned operational SHP plants with a combined installed capacity of 57.8 MW. More than 60 per cent of these plants have a capacity of less than 2.5 MW. There are also 52 operational micro-hydropower systems, ranging from 10 kW to 150 kW, with a combined installed capacity of 1.5 MW. There has been no comprehensive study of the country's hydropower potential. Therefore the country's SHP potential remains unknown.

In **Grenada**, there are no operational SHP plants. In the past, sugar cane estates used hydro wheels to operate mills, but none of these early hydropower stations are in operation today. Several studies have been undertaken to assess hydropower potential, which is estimated to be at least 7 MW. However, none of the identified sites have been developed yet.

The installed capacity of SHP in **Guadeloupe** is 11.1 MW, while total potential remains unknown. However, two feasibility studies identified an additional potential of 5 MW. Therefore, the SHP potential can be estimated to be at least 16.1 MW. Although the Government expressed the intention to increase the hydropower share in the country's energy mix, the development of these sites still remains in the planning phase.

The installed SHP capacity of **Haiti** is 6.96 MW, which comes from seven plants. Over the years, the available capacity of plants has decreased by almost a half due to ageing equipment and a lack of maintenance, and currently stands at 3.7 MW. The most recently commissioned plant is an 11 kW micro-hydropower plant installed in the small community of Magazen in the Nord-Est province in 2016. The country's untapped SHP potential is estimated at 13.95 MW.

Jamaica has eight SHP hydropower plants, which contribute approximately 30 MW to the grid. It should be noted that the Maggoty plant recently had an extension, which brought its total capacity above the 10 MW upper limit. Therefore, the plant is not included in the country's SHP total capacity anymore, which stands at 16.6 MW. In addition, 11 sites with approximately 29 MW of potential capacity have been identified as potential for hydropower development, indicating that 36 per cent of the known potential has been developed.

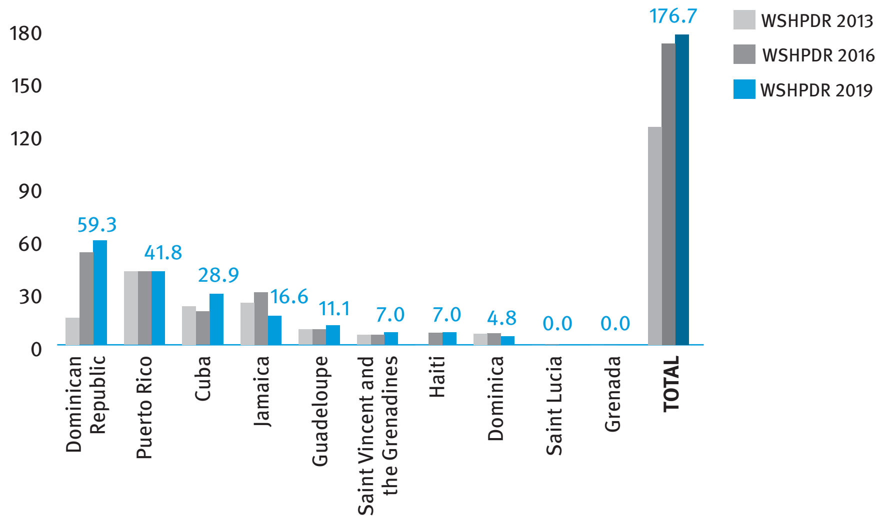
There are eight SHP plants in **Puerto Rico**, with an aggregated capacity of 41.8 MW distributed among 15 units. Before Hurricane Maria there were plans to redevelop a 3 MW plant at the Carraizo Dam, which had been destroyed in 1989 by Hurricane Hugo. SHP potential is estimated at 47.9 MW, indicating that almost 88 per cent of the known potential has been developed.

There are no hydropower plants operating in **Saint Lucia**. A small plant of 240 kW, which was installed at a small eco-touristic attraction at Latille Falls several years ago, is no longer operational due to the damage incurred during a storm. The country's SHP potential is estimated at 2.7 MW.

The installed capacity of SHP in **Saint Vincent and the Grenadines** is 7 MW. The potential capacity is estimated at 7.4 MW, which is based on the planned projects. However, considering the Government's ambitious renewable energy programmes, it may be assumed that the actual potential is much larger. A programme also exists that aims to modernize the existing plants in order to enhance their efficiency.

Most countries of the region have not introduced **feed-in tariffs (FITs)**. The Dominican Republic established incentives and FITs for renewable energy sources, but these do not apply to hydropower. In Puerto Rico, companies producing energy for domestic consumption can benefit from the Green Energy Fund programme. The Government of Puerto Rico also introduced tradable Renewable Energy Certificates (RECs), which support the development of the renewable energy sector.

Figure 3.
Change in installed capacity of small hydropower from *WSHPDR 2013* to *2019* by country in the Caribbean (MW)



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

Note: *WSHPDR* stands for *World Small Hydropower Development Report*.

Barriers to small hydropower development

In addition to the high exposure to extreme weather events, such as hurricanes, tropical storms and droughts, the countries of the region experience a range of other factors that hinder the development of SHP.

In most countries, hydropower development, including SHP, is beyond the focus of the energy objectives of the local Governments, with geothermal, solar and wind power being prioritized instead. One of the reasons for this is the high development costs of SHP projects. In addition, the legal frameworks in the countries of the region are not particularly conducive to SHP development, and do not provide economic and financial incentives to SHP projects.

Cuba also has a limited scientific and technological capacity for SHP development, which affects the technical and maintenance service of SHP plants, the availability of equipment, components and spare parts as well as the capability to carry out feasibility studies.

In **Dominica,** there is no established policy plan with regards to energy and electricity generated through hydropower. SHP development can also be complicated by land acquisition-related issues. **Saint Vincent and the Grenadines** also lack a specific plan on SHP development.

The **Dominican Republic**, **Grenada** and **Haiti** are still lacking comprehensive studies on SHP potential, which are critical for the further development of SHP. Additionally, SHP developers in the Dominican Republic face excessive bureaucracy, while in Haiti there is a lack of coordination among Government agencies and ministries.

In **Puerto Rico**, water resources are limited and used mainly for human consumption, and estimated hydropower potential is limited. Distributed micro-hydropower units represent a more realistic option for this country. However there is a lack of experience of this option.

The major water resources for micro- and small hydropower in **Guadeloupe** are located in a protected area, which restricts SHP development. The main rivers of **Saint Lucia** have generally low base flows, which does not allow the development of hydropower plants.

The water access situation in the region is further exacerbated by climate change.

References

1. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
2. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
3. LIU, D., LIU, H., WANG, X., and Kremere, E., eds. (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
4. World Bank (2017). *Rural population (% of total population).* Available from https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS
5. World Bank (2016). *Access the electricity (% of population).* Available from https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS
6. IPCC (2014). Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S.,mm Mastrandrea, P.R., White, L.L. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
7. IPCC (2014) Climate change 2014: impacts, adaptation, and vulnerability. Part B: regional aspects. Contribution of Working Group II to the Fifth Assessmment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., Field, C.B., Dokken, D.J., Mastrandrea, M.D., Mach, K.J., Bilir, T.E., Chatterjee, M., Eby, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R., White, L.L. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

2.1.1 Cuba

Conrado Moreno, World Wind Energy Association; International Center on Small Hydro Power (ICSHP)*

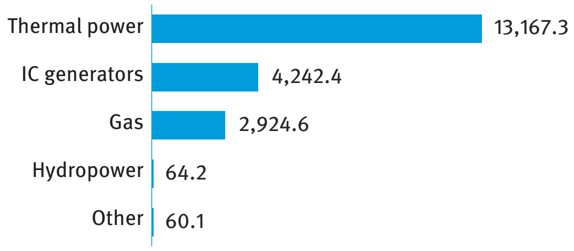
Key facts

Population	11,484,636[1]
Area	110,860 km[2]
Climate	Except in the mountains, the climate of Cuba is semi-tropical or temperate. The average minimum temperature is 21 °C and the average maximum is 27 °C. Trade winds and sea breezes make the coastal areas relatively cooler. Cuba has its rainy season from May to October. The eastern coast is often hit by hurricanes from August to October.[2]
Topography	Approximately a quarter of Cuba is mountainous with hills dotted across the whole island, alternating with plains, and three main mountain ranges – the Guamuhaya (or mountains of the Escambray), the Guaniguanico and the Maestra. The Maestra, located in the south-east, is the largest mountain range and home to Pico Real de Turquino, the country's highest peak at 2,005 metres.[2]
Rain pattern	The rainy season is from May to October. The mountain areas experience an average annual precipitation of more than 1,800 mm, while most of the lowland regions range from 900 to 1,400 mm. The area around Guantánamo Bay in the south-east receives less than 650 mm of precipitation a year. Droughts are common in Eastern Cuba, but recently have also heavily affected the western and central regions.[2]
Hydrology	The topography and climate of the island tend to result in short rivers with reduced flows. The longest river is the Cauto, at 249 km, flowing westwards north of the Sierra Maestra. Other major rivers include the Sagua la Grande and the Toa.[2]

Electricity sector overview

In 2016, total annual generation was approximately 20 TWh. Generation was dominated by fossil fuel based thermal power plants, including gas-powered turbines and generation from industries, which contributed approximately 78 per cent. Grid-connected internal combustion (IC) generators contributed 21 per cent, while hydropower and other renewable energy sources (including wind and solar power) contributed 0.6 per cent combined (Figure 1).[3]

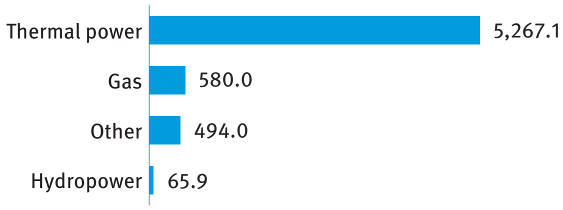
Figure 1.
Annual electricity generation by source in Cuba (GWh)



Source: ONEI[3]

In 2016, installed capacity totalled 6,407 MW, with approximately 82 per cent from thermal power plants, including diesel-powered generators, 9 per cent from gas turbines, 8 per cent from other sources, including generators operated by the Ministry of Basic Industry and Grupo Azucarero (AZCUBA), and 0.01 per cent from hydropower (Figure 2).[3]

Figure 2.
Installed electricity capacity by source in Cuba (MW)



Source: ONEI[3]

In Cuba, 100 per cent of the population have access to electricity.[5] Total electricity consumption rose by 36 per cent between 2000 and 2016, reaching 20,459 GWh in 2016. The residential and public sectors consumed approximately 43 and 42 per cent, respectively. Losses amounted to approximately 15 per cent.[3]

* *WSHPDR 2016* updated by ICSHP

The electricity sector in Cuba is completely publicly owned by Unión Eléctrica de Cuba (UNE), which is part of the Ministry of Energy and Mines, and responsible for the generation, transmission and distribution of electricity. The National Institute for Hydraulic Resources (INRH) is the regulatory authority for hydropower and water resources. Over the last decade, the electricity industry has undergone significant reforms, which began in 2005 with a new energy development strategy known as the Energy Revolution. The promotion of distributed generation, electric grid rehabilitation, energy saving and energy education and the growing use of renewable energy sources are key features of this strategy. Development of the National Electric System has focused on decreasing the share of oil-based thermal power plants and an increase in the use of coal, liquid natural gas and biomass.[6,7,8]

More recently, the share of combined cycle and IC generators has risen, resulting in a move away from a concentrated system composed of large thermoelectric power plants towards a system of distributed generation. This in turn has reduced the consumption of fossil fuels with the energy efficiency of IC generators being higher than that of the large thermoelectric power plants. The reduced concentration of the country's generation capacity in large thermoelectric plants has also reduced the risks posed to the system by hurricane damage.[8]

Alongside other measures undertaken as part of the Energy Revolution, electricity tariffs were readjusted. As of 2018, electricity tariffs were CUP 0.09 (US$0.09) per kWh for households consuming 0-100 kWh/month. Each additional kilowatt per hour with a consumption of 101-150 kWh/month costs CUP 0.3 (US$0.3). Prices subsequently increase according to the monthly consumption (Table 1).[8,9]

Table 1.
Electricity tariffs

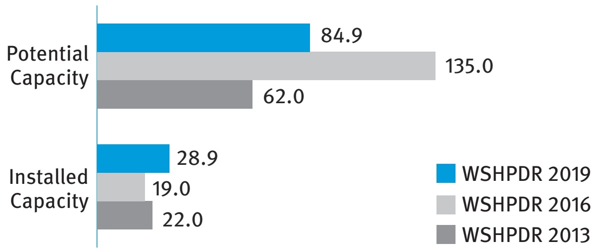
Consumption (kWh)	*Price (US$/kWh)*
0-100	0.09
101-150	0.30
151-200	0.40
201-250	0.60
251-300	0.80
301-350	1.50
351-500	1.80
501-1,000	2.00
1,001-5,000	3.00
>5,000	5.00

Source: Buro O-Quadrat[9]

Small hydropower sector overview

There is no official definition of small hydropower (SHP) in Cuba. However, this report assumes a definition of plants with an installed capacity of less than 10 MW. The current installed hydropower capacity is 71.9 MW, with 43 MW from the Hanabanilla plant and 28.9 MW from micro-, mini- and small hydropower.[4] The total potential of SHP is unknown, but based on the planned projects it is possible to conclude that there is at least 56 MW of undeveloped potential.[4] This indicates that approximately 34 per cent of the known SHP potential has been developed. In comparison with data from the *World Small Hydropower Development Report (WSHPDR) 2016,* Cuba's installed capacity has increased by 52 per cent, while potential capacity decreased by 37 per cent, based on a more accurate estimate (Figure 3).

Figure 3.
Small hydropower capacities 2013/2016/2019 in Cuba (MW)



Source: MINEM,[4] *WSHPDR 2016*,[8] *WSHPDR 2013*[10]

Note: The comparison is between data from *WSHPDR 2013, WSHPDR 2016* and *WSHPDR 2019.*

There are 161 SHP plants in Cuba, 33 of which are connected to the national grid, while the other 128 plants are off-grid. Hydropower, including the 43 MW Hanabanilla plant, serves 8,486 households and 416 economic entities in the country. The total technical hydropower potential of Cuba is estimated at 135 MW.[4] Beginning with the conversion of existing dams and water channels, a programme has been initiated by the Government for the construction of 74 SHP plants with a combined capacity of more than 56 MW and an estimated annual generation of 274 GWh (Table 2).[4,8,11] In 2018, the 3 MW Alacranes hydropower plant in Villa Clara was expected to be completed.[4]

Table 2.
Small hydropower projects

Location	*Number of projects*	*Total capacity (MW)*
Artemisa	2	0.89
Camagüey	11	5.00
Cienfuegos	6	1.86
Granma	6	5.37
Guantánamo	4	3.81
Holguín	4	4.58
Matanzas	3	0.48
Mayabeque	4	0.60
Pinar del Río	12	4.00
Sancti Spíritus	5	10.40
Santiago de Cuba	5	13.13
Villa Clara	12	5.970
Total	**74**	**56.09**

Source: MINEM[4]

In 2016, Cuba signed an agreement with the Kuwait Fund for Arab Economic Development (KFAED), which will provide US$30 million for the construction of 34 SHP projects with a combined capacity of 14.6 MW. These are to be constructed on existing infrastructure. The agreement also includes the construction of three linking substations that will transmit electricity to the national grid, along with approximately 75 km of transmission lines. The duration of the project is seven years.[12]

Renewable energy policy

The two key challenges for the Cuban electricity sector are the high cost of generation, approximately CUP 4.67 (US$4.67) per kWh, and heavy dependence on oil imports. For these reasons, the Council of Ministers and the Cuban Parliament approved the Policy for the Prospective Development of Renewable Energy Sources and the Efficient Use of Energy for 2014-2030 in July 2014, with the aim of diversifying the energy mix, taking into account the use of all possible renewable energy sources.[8]

The main objectives of the policy are:

- To reduce the dependence on fossil fuels and thus increase energy independence
- To decrease the high consumer cost of energy stemming from both the cost of fuel and the low efficiency of the electricity system
- To contribute to environmental sustainability
- To introduce a new law governing foreign investment.[8]

While the new law governing foreign investment (Law 118-2014, replacing Law 77-1995) does not include specific legislation for renewable energy sources, the Government, through several directive documents, has recognized the decisive role that renewable energy sources have to play in the future development of the country. The Environmental Law (Law 81-1997) lay the foundations for this recognition, and has been subsequently added to over the past two decades. With regard to hydropower, Resolution 114-1990 gives authority to the INRH to approve the entities that are authorized to construct any project related to water, including foreign entities.[8,13]

Foreign investment contributes to the change in the energy mix of Cuba, through the development of solar power, wind power, hydropower, biogas and agricultural and industrial residuals such as sugarcane biomass. With the Cuban Programme to Combat Climate Change (el Programa Cubano de Enfrentamiento al Cambio Climático) of 2007 and the 2012 National Water Policy (La Política Nacional del Agua 2012), efficient and responsible management and utilization of water resources have become a national priority. Thus, the Government is open to investment from foreign enterprises in renewable energy projects, by means of either joint ventures with Cuban enterprises or totally foreign investment.[8,14,15]

Following the power shortages of mid-2017, the development of indigenous renewable energy resources has become particularly pressing for the Government of Cuba. In January 2018, it held the Cuba Sustainable Energy Forum in Havana, which was attended by participants from the European Union, international energy companies and the private sector. Attracting foreign investment is critical to the Government's goal of achieving US$3.5 billion of investment into the sector. In this context, Cuba has been strengthening its engagement with the International Renewable Energy Agency (IRENA) through the SIDS Lighthouses Initiative.[16]

In March 2018, the Government signed Law 345 on the Development of Renewable Sources and the Efficient Use of Energy, which sets the target of achieving a 24 per cent share of renewable energy in the country's energy mix by 2030. The Law also makes provisions for tariff exemptions for the imports of components and equipment for renewable energy projects.[17]

Barriers to small hydropower development

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

- A lack of development projects
- Limited financial resources
- A lack of specialists in technical and maintenance service
- The limited ability of national industry to ensure the availability of equipment, components and spare parts
- Low usage of the existent production capacities
- The limited scientific and technological capacity of the water sector
- Limited capacity to carry out feasibility studies
- Insufficient maintenance of existent facilities.[8,18,19]

References

- World Bank (2017). *Population, total*. Available from http://data.worldbank.org
- Nations Encyclopedia (n.d.). *Cuba*. Available from www.nationsencyclopedia.com/Americas/Cuba.html
- Oficina Nacional De Estadistica e Informacion (ONEI) (2017). *Anuario Estadistico de Cuba 2016. Minería y Energía*. Available from http://www.one.cu/aec2016/10%20Mineria%20y%20energia.pdf
- Ministerio de Energía y Minas (MINEM) (n.d.). *Hidroenergía*. Available from https://www.minem.gob.cu/energias-renovables
- World Bank (2016). *Access to electricity (% of population)*. Available from https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS
- Rojas, D. R. (2014). *Energía en Cuba: iniciativa local y gestión no estatal para fuentes renovables*, Progreso Semanal, 28 July 2014
- Presentation of the former Ministry of Energy and Mines in the International Conference of Renewable Energy (CIER 2009), June 2009, Havana, Cuba.
- CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds.

(2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.

- Buro O-Quadrat (2013). *Cuban Energy Revolution –A Model for Climate Protection?* Available from http://www.oe2.de/fileadmin/user_upload/download/Energierevolution_Cuba_eng.pdf
- LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
- Cuban Ministry of Foreign Commerce and Investment (2014). Portfolio of Opportunities for Foreign Investment. Cartera de Oportunidades para la Inversión Extranjera, La Habana, 2014
- International Hydropower Association (IHA) (2018). *Cuba*. Available from https://www.hydropower.org/country-profiles/cuba
- Centre for Information Management and Energy Development (CUBAENERGIA); Latin American Energy Organization (OLADE); UNIDO (2012). *Observatory of Renewable Energy in Latin America and the Caribbean: Cuba, Final Report*
- Moreno, C. (2012). *Leyes para las energías renovables en América Latina y el Caribe.* Published in the review *Energia y tu*, 2012, Havana, Cuba. Available from www.cubasolar.cu.
- Presentation of the Strategy Development of Minister of Energy and Mines, *Meeting of the Energy Network Universities,* January 2014
- International Renewable Energy Agency (IRENA) (2018). *Embracing Renewables in Cuba.* Available from http://www.irena.org/newsroom/articles/2018/Feb/Embracing-Renewables-in-Cuba
- Bellini, E. (2018). *Cuba introduces net metering for solar, renewables.* PV Magazine, 16 April 2018. Available from https://www.pv-magazine.com/2018/04/16/cuba-introduces-net-metering-for-solar-and-renewables
- Echeverria, J. A. (2012). *Technical Report of Expert Group of Higher Polytechnic Institute*.
- Centro de Gestión de la Información y Desarrollo de la Energía (CUBAENERGIA) (2013). *Technology Needs Assessment (TNA) on Climate Change – Adaptation Final Report (Cuba)*. Available from www.tech-action.org

2.1.2 Dominica

Sven Homscheid-Carstens, Hydropower Consultant; and International Center on Small Hydro Power (ICSHP)

Key facts

Population	73,543 [1]
Area	751 km^2 [2]
Climate	The climate of Dominica is tropical wet, characterised by heavy rainfall and warm temperatures. The North-East trade winds pattern can develop into hurricanes, these most likely occurring during the wettest months. Temperatures rarely fluctuate and the average temperature throughout the year is 26°C, with a deviation of only +/-1°C among the monthly averages.[2] Average daytime temperatures in winter are about 26 °C, while in summer these reach 32 °C.[3]
Topography	Dominica is surrounded by the Atlantic Ocean in the East and the Caribbean Sea in the West. Roughly 48 km to the north is the French Island of Guadeloupe, while Martinique is 40 km south of Dominica. Considered the largest and most northerly of the Windward Islands, the country is also part of the rugged Lesser Antilles volcanic arc. Its vegetation is lush and green, with dense forests and a tropical flora on steep slopes. The axis of volcanic slopes in Dominica varies in elevation from 300 to 1,400 metres above sea level. Its highest peak is Morne Diablotins, which reaches 1,447 metres.[3]
Rain pattern	The weather in Dominica is characterized by strong rains, with rainfall ranging from 2,000 mm at sea level to above 8,000 mm in the mountainous area. The island has both a rainy and a dry season, the former between July and December and the latter from January to June.[3]
Hydrology	Dominica is water-rich, containing 365 rivers as well as many waterfalls which are evenly dissipated across the country. The Layou, Roseau and Toulaman are the major rivers. Most streams are non-navigable but can be used for hydropower generation.[3]

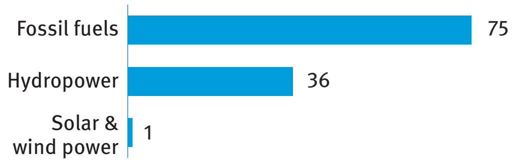
Electricity sector overview

Total electricity generation in Dominica was 112 GWh in 2016, according to UN data (Table 1). Electricity production from hydropower increased to an overall 36 GWh, while the use of fossil fuels slightly decreased, accounting only for 75 GWh, with 1 GWh from solar and wind power. Hydropower accounts for 32 per cent of the total electricity generated, while fossil fuels, mostly diesel, represent roughly 67 per cent.[4] The total installed capacity of electric power plants in 2016 was 27 MW. Hydropower accounted for 7 MW.

In 2014, the electrification rate of Dominica was 100 per cent.[4] However, due to Hurricane Maria in 2017, the vast majority of the population still does not have access to electricity. The damages were estimated at US$ 930.9 million. The agricultural, transport and tourism sectors suffered a further US$ 380.2 million in losses. Roughly US$ 1.3 billion, or 224 per cent of the country's GDP in 2016, was lost as a result of the devastating hurricane. In January 2018, four months after Hurricane Maria hit, 90 per cent of the population still did not have access to electricity.[14]

Therefore, electricity transmission and distribution systems in Dominica have changed significantly and differ from the pre-Hurricane Maria numbers. Also, many of the electricity generation units were severely affected, including the Padu hydropower plant. According to the 2017 Annual Report of Dominica Electricity Services Limited (DOMLEC), by the end of December 2017 about 19.7 of the country's total installed capacity of 27 MW were operational. However, the actual demand was much lower due to a lack of connection lines.[17]

Figure 1.
Annual electricity generation by source in Dominica (GWh)



Source: UN[4]

Note: Data from 2016.

The monopoly on the transmission and distribution of electricity in Dominica is held by DOMLEC. While the energy supply was considered expensive in 2014, due to the non-harmonious distribution of the population, DOMLEC is actively attempting to reduce electricity costs. According to the 2016 annual report, DOMLEC customers benefited from a decrease in fuel surcharge on electricity from US$ 0.23 per kWh in December 2015 to US$ 0.21 per kWh in December 2016. In addition to declined fuel prices, the decrease was also a result of increased hydropower generation.[5]

There are independent power producers in Dominica such as the 275 kW Rosalie wind turbine that produces 596 MWh annually. The wind turbine was installed by Rosalie Bay Resort. A turbine of 1 kW is also in operation, but is not connected to the grid.[6]

Frequent tropical storms such as Tropical Storm Erika in 2015 and Tropical Storm Matthew on September 28, 2016 adversely affect customer supply and thus access to electricity in Dominica. During Tropical Storm Matthew, disruption to 26,345 DOMLEC customers was caused, yet at this time supply, was restored within six days.[5] The hurricane season of 2017, with Hurricane Maria on September 18 and Hurricane Irma a week before, caused severe damage to the island's infrastructure and changed the electricity sector for a prolonged time. The re-establishment of the electricity supply grid and the recovery of the electrification rate to 100 per cent are still ongoing and may take some time.[17]

The Government of the Commonwealth of Dominica owns 20 per cent of DOMLEC shares, while 80 per cent is owned by private investors.[7] In 2016, the Independent Regulatory Commission (IRC), which acts as regulatory body of DOMLEC, approved the Distributed Renewable Energy Generation Policy and the Codes on Generation, Transmission, Distribution and Supply. While efficiency of renewable energy promotion by IRC has been limited, during 2016 the Government and DOMLEC planned the implementation of a national geothermal project.

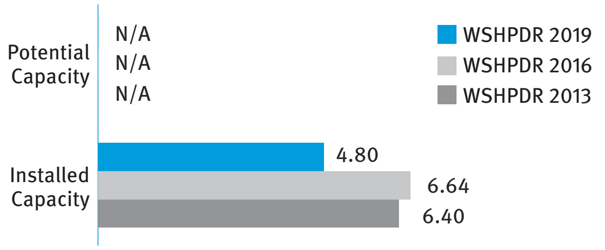
The company's sustainable energy initiative has a limited effect on independent power producers and most improvements are made at an office level within the company itself. Smart energy efficiency offices led to an average usage reduction of 10,000 kWh per month at DOMLEC. The company electricity sales increased by 4.7 per cent in comparison to 2015 figures, while its customers reported considerably higher satisfaction in the services provided.[5]

Small hydropower sector overview

The definition of small hydropower in Dominica refers to plants of up to 10 MW. The installed capacity of SHP was 4.8 MW, according to data for the end of 2016.[15] The country had three operational SHP plants Laudat, Trafalgar and Padu – all are owned by DOMLEC. Recent data on the individual capacity of plants, particularly after Hurricane Maria, has not been made available. The previous DOMLEC report put the estimated installed capacity of the Laudat plant at 1.3 MW and that of the Trafalgar plant at 3.52 MW. The Padu plant was destroyed by Hurricane Maria and as of the end of 2018 was still not operational. Therefore current small hydropower capacity in Dominica may be around 4.8 MW.

Dominica expanded its electricity generated through hydropower by implementing the Dominica Hydroelectric Expansion Project, which led to a new hydropower station, the Laudat power station, commencing its service in December 1990. The Old Trafalgar power station was replaced by the New Trafalgar in September 1991.[8] DOMLEC declared small hydropower an essential source of electricity and an excellent alternative to fossil fuels. Therefore, both the public and private sector plan to further disseminate SHP in the country.[5]

Figure 2.
Small hydropower capacities 2013/2016/2019 in Dominica (MW)



Source: *WSHPDR 2016*,[12] IRENA,[15] *WSHPDR 2013*[17]

Note: The comparison is between data from *WSHPDR 2013, WSHPDR 2016* and *WSHPDR 2019.*

In 2017, Hurricane Maria severely affected the entire country, including its existing hydropower facilities. Most of the country suffered severe losses, and damage to electrical generation sites and transformers caused over 75 per cent of the network to collapse. According to the Relief Web post-disaster report, 80 to 90 per cent of the inspected transformers were damaged beyond repair and the generation sites also suffered moderate to severe damages. A study of the Roseau river area found that the Trafalgar hydropower plant only experienced minor damages to the building structure, while the Laudat plant remained intact.[18] The Padu hydropower station was severely affected, with the flooding of its powerhouse and damage to its electrical installations.[17]

A hydropower project analysis was proposed by the Caribbean Renewable Energy Development Programme (CREDP-GIZ). The study investigated generating power from an existing bulk water pipeline, which takes water from Padu and transports it to the shores in Roseau. Dominica Water and Sewerage Corporation (DOWASCO) owns the water pipeline and it was discovered that installing an electricity-generating 200 kW turbine at the end of the pipeline was both technically and financially feasible. The project has not yet been implemented, and is pending a positive investment decision from the water utility.

A qualitative hydropower potential assessment indicated there was a significant hydropower potential in Dominica. The Belfast, Layou, Rosalie, Roseau and White rivers were identified as highly promising for hydropower project implementation. However, the undertaken study did not quantify the potential.[7,9]

Renewable energy policy

A National Energy Policy Plan was drafted in 2011 and revised in 2014, asserting the country's objective for self-sufficient electricity generation through sustainable resources by 2020.

It is essential to mention that the policy does not set binding targets. Geothermal production of 120 MW was estimated to be fully operational by 2020. The country's successful use of solar power and its diversity in terms of renewable energy sources is believed to attract future foreign green investment.[10]

All sustainable development programmes and projects in Dominica are coordinated by the Environment Coordinating Unit (ECU). The ECU is funded primarily by internal sources and collaborates with the Government of the Commonwealth of Dominica and the private sector agencies on developing renewable energy policies as well as tackling environmental issues. Since mid-2015, there were no changes to the existing energy policy. The National Energy Policy Plan implementation and ratification was also postponed. The lack of an established incentive mechanism for the renewable energy adoption and implementation may further prevent further development initiatives in the sector.[7,10]

The joint collaboration of the European Union (EU), the Regional Councils of Martinique and Guadeloupe, the French Agency for Environment and Management of Energy, the French Geological Survey (BRGM) and the Government of Dominica led to further scientific discoveries with regards to geothermal potential. Favourable conditions for electricity generation arising from the country's volcanic physiography were identified.[10] Hydropower project costs in Dominica, as well as the lack of feed-in tariffs (FITs) and additional financial incentives help to explain the slow progress the industry has made since 2011. The low cost of fossil fuels such as diesel and the rapid development of eco-tourism, which resulted in frequent use of rivers, make it difficult to adopt and implement future hydropower projects.[7]

Barriers to small hydropower development

There are multiple barriers to SHP development and dissemination in Dominica:

- The current focus on electricity generated through geothermal resources has shifted the Government interest away from other RE sources.
- Progress in eco-tourism and the frequent use of rivers for this purpose prevents future hydropower development.
- There is a lack of an established policy plan with regards to energy and electricity generated through hydropower.
- Dominica lacks economic and financial incentive mechanisms for SHP, such as FITs. External investment in SHP may also be limited due to the current tariff offered by DOMLEC.
- Hydropower project development costs are considered high.
- Privately-owned properties make land-acquisition for hydropower difficult.[7]

In addition to the barriers to hydropower mentioned above, the country was recently devastated by Hurricane Maria. The efforts of the Government will focus on re-establishing the general power supply, and much of the national budget and other efforts will be used for that exercise before efforts may be made to expand the hydropower sector in Dominica.

References

1. World Bank (2016). *Population, total.* Available from http://data.worldbank.org.
2. Government of the Commonwealth of Dominica. Fast Facts: Dominica. Available from http://cbiu.gov.dm/fast-facts/ . Checked on April 2018.
3. United States Library of Congress (1987). *Caribbean Islands: A Country Study*. Available from www.countrystudies.us.
4. UN data (2016). Total Electricity Generation: Dominica. Energy Statistics Database. Available from http://www.data.un.org
5. Dominica Electricity Services LTD. (2017). *Annual Report 2016.* Available from www.domlec.dm.
6. National Renewable Energy Laboratory (NREL) (2015). *Energy Transition Initiative, Islands: Dominica.* Department of Energy. Office of Energy Efficiency. www.nrel.gov
7. Sven Homscheid (2016). *World Small Hydropower Development Report 2016: Dominica.* International Centre on Small Hydropower and the United Nations Industrial Development Organization.
8. The Organization of American States (OAS) (2001). *Natural Hazards Vulnerability of the Dominica Hydroelectric Expansion Project*. Unit of Sustainable Development and the Environment.
9. Grett, J. P. and Fay, T. (2013). *Hydropower Potential Analysis – Dominica.* CREDP-GIZ. Available from www.credp-giz.org.
10. United Nations Sustainable Development Knowledge Platform (2015). *National Report: Dominica.* Documents & Reports. Available from https://sustainabledevelopment.un.org
11. Government of the Commonwealth of Dominica (2011). *National Energy Policy*.
12. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016.* United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
13. The Central Intelligence Agency (CIA) Data (2015). *Dominica Energy*. Available from www.cia.gov
14. Reliefweb Country Data (2018). *Dominica: The Impact of Hurricane Maria, Disaster Profile.* January 2018. Available from www.reliefweb.int.
15. International Renewable Energy Agency (IRENA) (2017). Medium Hydropower (1-10 MW). Available from http://www.irena.org
16. The Sun (2016). DOMLEC takes press on tour of hydro-plant. The declaration of David Stamp, Generation Manager of DOMLEC. Available from http://www.sundominica.com
17. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013.* United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
18. Reliefweb Country Data (2018). ACAPS Disaster Profile: Dominica. Available from https://reliefweb.int/sites/reliefweb.int/files/resources/20180131_acaps_disaster_profile_dominica_v2.pdf
19. DOMLEC Annual Report 2017 (2017). Available from http://www.domlec.dm/pdf/DomlecAR2017.pdf

2.1.3

Dominican Republic

Alberto Sánchez, GEF Small Grants Programme; Michela Izzo, Guakia Ambiente

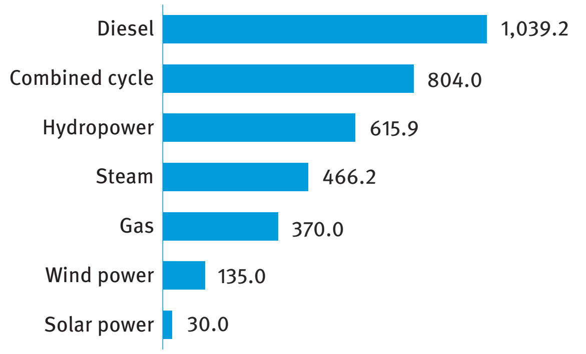
Key facts

Population	10,648,790[1]
Area	48,311 km²
Climate	The climate of Dominican Republic is tropical humid, with high ecosystem diversity, ranging from arid to very humid. This is due to the country's physical geography, characterised by mountain chains which create a barrier to trade winds, producing very different conditions between the windward and leeward sides. The average temperature ranges between 7 °C (at the highest altitudes) and 31 °C (in the Enriquillo Lake in the southern region).[2, 24]
Topography	The Dominican Republic has four main mountainous chains – the Cordillera Septentrional, Cordillera Central, Sierra de Neyba, and Sierra de Bahoruco. These chains run approximately parallel to each other with a north-west, south-east orientation and are separated by three major valleys – the Cibao, San Juan, and Enriquillo. Pico Duarte, which reaches 3,098 metres, is the highest peak in the country, on the island of Hispaniola and in the entire Caribbean.[2, 24]
Rain pattern	The orientation of the mountain chains can cause variations in precipitation of up to 2,400 mm between the north-eastern and south-western sides of the Cordillera Central. The wettest areas are located in the north-eastern of the country, which receive annual rainfalls of over 3,000 mm, while the driest areas can be found in the Enriquillo Valley, in the south-west, with less than 450 mm per year.[2, 24]
Hydrology	The Yaque del Norte (296 km) is the longest river in the Dominican Republic. The longest river on the island of Hispaniola is the Artibonite river (321 km), however only 68 km of it is located in the Dominican Republic. Lake Enriquillo is the largest lake not only in the Dominican Republic but in the entire West Indies.[2, 24]

Electricity sector overview

According to official data, total installed capacity in the Dominican Republic stood at 3,460.3 MW in 2016. Approximately 30 per cent came from diesel engines, 23.2 per cent from combined cycle power plants, 13.5 per cent from steam turbines, and 10.7 per cent from gas turbines. Renewable energy sources contributed 22.6 per cent of the total, with hydropower plants providing 17.8 per cent and wind power plants 3.9 per cent (see Figure 1).[3]

Figure 1.
Installed electricity capacity by source in the Dominican Republic (MW)



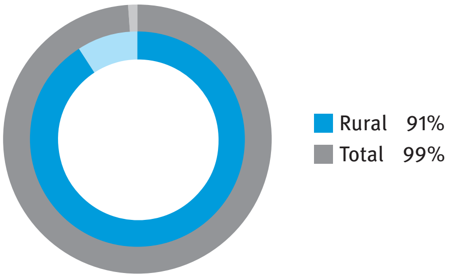
Source: SIEN[3]

Total gross electricity generation in 2016 reached 15,891.8 GWh. Diesel and fuel oil contributed approximately 51.5 per cent, natural gas 23.3 per cent, coal 13.6 per cent, hydropower 9.5 per cent, wind power 2.0 per cent and solar power 0.2 per cent.[4]

The Dominican electricity system is characterized by low service reliability. Despite progress in recent years, energy generated and distributed is insufficient to fulfil the national demand, both of residential and commercial users. This generates frequent interruptions in provision. Furthermore, there is a high loss rate in the transmission and distribution systems, which exceeds 33 per cent of the total electricity generated.[5] For these reasons, the provision of electricity is still a major problem of the country. One per cent of the total population and 9 per cent of the rural population does not have access to electricity.[6]

In 2017, the Dominican Republic was ranked 125 out of 137 countries analysed for quality of electricity supply.[7] Despite the fact that electricity generation exceeds demand, interruptions are frequent due to inefficiency and losses in the transmission and distribution system.

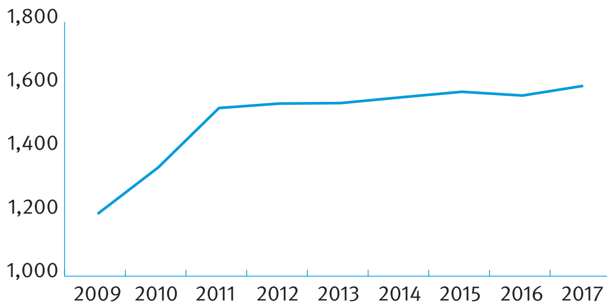
Figure 2.
Electrification rate in the Dominican Republic (%)



Source: IEA[6]

The country continues to be highly dependent on imported fossil fuels. Due to one of the highest GDP growth rates in the region, the country has been demonstrating an upward trend in energy demand and consumption since 2009. The electricity expenditures of the residential and the commercial sectors have increased by more than 29 per cent (see Figure 3).[8] National projections indicate that energy demand will continue to grow at an average rate between 2.5 and 3.0 per cent per year for the residential sector, between 3.3 and 4.7 per cent per year for the services sector and between 3.6 and 5.2 per cent for industry.[9]

Figure 3.
Energy sales to regular commercial and residential customers in the Dominican Republic 2009 - 2017 (US$ thousand)



Source: CDEEE[8]

The Dominican electrical system is state-owned. However, both the Government and the private sector participate in generation, transmission, distribution and commercialisation of energy. The Coordinator of the National Interconnected System (OCSENI) is the State agency responsible for coordinating the transmission, generation and distribution within the National Interconnected Electric System (SENI). Through *Law 141-97*, five enterprises were created, two for thermal generation (Electricity Generation Enterprises ITABO and HAINA - EGEITABO and EGEHAINA respectively) and three for distribution (Electricity Distribution Enterprises of the North, South and East - EDENORTE, EDESUR and EDEESTE respectively). Both transmission and hydropower generation are the responsibility of the State. The Dominican Corporation of State Electrical Enterprises (CDEEE) is responsible for the management of electrical enterprises and implementation of State programmes for rural and urban electrification, guaranteeing synergy, effectiveness, profitability and sustainability.[24]

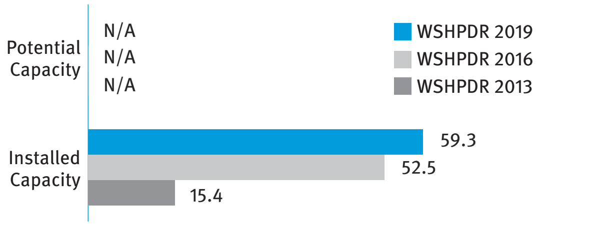
The Dominican Republic has one of the most expensive electrical structures in the Caribbean and Central America,[5,10,11] with final customers having to pay more than US$ 0.20 per kWh in 2017. This is more than three times the US$ 0.06 per kWh that people pay in the 16 off-grid, community-owned Small Grants Programme hydropower plants outlined below.[25]

Two different types of Government subsidies exist. Firstly, there is the "Bonoluz, 3 en 1", which is a direct subsidy up to 100 kWh to customers who have been selected by the Social Cabinet of the Government. For additional consumption, a further subsidy is provided in the form of a lower tariff. Finally, these customers receive a subsidy for the fixed charge as well. The second type of subsidy is the Fund for the Stabilization of the Electric Tariff (FETE) which is based on tariff differences and tries to compensate for the high cost of fuels.[24]

Small hydropower sector overview

In the Dominican Republic, the total installed hydropower capacity is 615.9 MW. Hydropower is the country's most important energy source after fossil fuels. In the country, small hydropower (SHP) is classified as plants with a total capacity of no more than 10 MW.[3,12,13] The installed capacity of SHP is approximately 59.3 MW, contributing 9.5 per cent to the total hydropower installed capacity.[12,13] The recent increase in small hydropower can be explained due to recent data being made available on hydropower plants under 1 MW.

Figure 4.
Small hydropower capacities 2013/2016/2019 in the Dominican Republic (MW)



Source: EGEHYD,[12] Sánchez et al.,[13] *WSHPDR 2013*,[23] *WSHPDR 2016*[24]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019.*

Sixteen state-owned small hydropower plants are operational with a combined installed capacity of 57.8 MW. More than 60 per cent of the plants have a capacity of less than 2.5 MW. The majority of the plants are located in the Cordillera Central, the main mountain chain of the country, and contribute more than 80 per cent of the installed capacity. The average capacity factor of small hydropower plants is about 45 per cent. In addition, there are 52 operational micro-hydropower systems, ranging from 10 kW to 150 kW, with a combined installed capacity of 1.5 MW.

A comprehensive study on hydropower potential in the Dominican Republic has not been carried out. Such a study is necessary for further small hydropower development however, due to the climate and topography of the country, considerable potential can be expected, in particular on the Cordillera Central, the largest massif in the country. In 2018, a study of this nature is planned to start, as a part of a collaboration among the Ministry of Energy and Mines, the GEF Small Grants Programme, the Technological Institute of Santo Domingo (INTEC) and Guakía Ambiente, a Dominican NGO.[25]

In the last ten years, following the approval of the Renewable Energy Incentive Law (Law 57-07), there have been considerable developments in community micro-hydropower systems. With the leadership of the GEF Small Grants Programme and Guakía Ambiente, a Dominican NGO, a highly sustainable model, based on local empowerment and the synergic work of a multi-stakeholder platform, constituted by public institutions, private sector, international cooperation agencies, as well as civil society. Through this work, the above mentioned 52 micro-hydropower plants (1.5 MW combined installed capacity) were successfully established as community-owned systems. Together they are providing a continuous energy service to more than 4,500 families, schools, rural health and community centres, micro-enterprises and communication centres in rural isolated areas. In addition, CO_2 has been reduced by more than 28,000 tons per year and over 70 km^2 of forest were conserved.[13,14,15,16,17] The sustainability of the model is based on some key elements:

- Emphasis on community autonomy with regards to the management of the systems, making them responsible for both technical and financial administration
- Synergies among numerous stakeholders, who work under shared principles
- Networking, oriented to reducing systems' vulnerability and improving community capacity to afford any event related to micro hydropower generation.

The multi-stakeholder platform now includes the Dominican Government, the Suburban and Rural Electrification Unit (UERS) and EGEHID, local governments, national NGOs, the United Nations, the European Union, the Inter-American Foundation, and the private sector.[14,18,19,20]

To support these principles, the Dominican Network for the Sustainable Development of Renewable Energy (REDSER) was constituted, as the national community-based organization that looks after the sustainable management of community systems, guaranteeing specialised technical assistance, capacity building, among other services. More than 50 community-based organizations are members of the REDSER.

As of 2018, a further ten systems were under construction, with a total capacity of more than 600 kW, and a number of additional communities were requesting similar projects.[13] The Dominican Republic has a huge potential for developing this kind of initiatives and the planned study on small hydropower potential will evaluate it. At present, the GEF Small Grants Programme estimates that more than 100 similar initiatives could be developed in the country.[13] In this regard, a specific challenge is the strengthening of the multi-stakeholder platform, improving coordination and expanding participation, with special focus on private sector, which can contribute to increasing the number of potential financial sources and promoting local entrepreneurship. In total, more than US$ 20 million have been invested in mini- and micro-hydropower systems since 2010.[12,13]

Renewable energy policy

The Dominican policy on renewable energy is defined by the Incentive to the Development of Renewable Energy Sources (Law 57-07) and the corresponding regulations (No. 10469 of May 30, 2008). The law introduced a target of 20 per cent of the national energy consumption produced from renewable energy sources by 2020, with the aim of reducing the dependence on imported oil and other liquid fuels. This goal is confirmed by the National Strategy of Development 2030 (Law 01-12), where the Dominican Republic established the goal of reducing 25 per cent per capita CO_2 emission with respect to the 2010 baseline. These goals will be reached through structural interventions to improve the national electric system, as well as changes in national energy matrix. The Dominican Government will continue promoting renewable energy sources, which are planned to reach 23.3 per cent of the energy generated at national scale in 2030.[5]

The Regulation for the Application of Law 57-07 establishes incentives and feed-in tariffs for renewable energy sources, according to the specific type however these do not apply to hydropower, small or otherwise (see Table 1).

Table 1.
Feed-in tariffs in the Dominican Republic for renewable energy sources

Type	*Tariff (US$/kWh)*
Wind connected to SENI:	0.1252
Wind from auto-production to be sold to SENI	0.0487
Electricity from biomass connected to SENI	0.116
Electricity from biomass from auto-production to be sold to SENI	0.0487
Electricity from Solid Urban Waste to be sold to SENI	0.085
Photovoltaic connected to national grid (power > 25 kW)	0.535
Photovoltaic from auto-generation to SENI (power > 25 kW)	0.1

Source: Government of the Dominican Republic[19]

Barriers to small hydropower development

The main barriers continue to be the same as in previous years. Specifically, the following main points can be stressed:

- Lacking a study on small hydropower potential at the national level
- Engagement of private sector in the development of new initiatives
- Opening of opportunities for feeding directly the grid up to 5 MW
- Directly engaging local communities in dissemination of SHP initiatives has been challenging because of lack of awareness with regards to benefits of small hydropower
- Lack of a network to facilitate knowledge exchange and to promote mutual support, while focusing on tackling existent issues in the energy sector
- Decentralization in decision making
- Lengthy time needed to complete administrative procedures, especially when community initiatives are developed
- Climate change effects and the degradation of main watersheds in the country
- Shortage of data is a continuous issue and a comprehensive study on mini and micro hydro potential of Dominican Republic would be essential to future small hydropower development.[24]

References

1. The World Bank (WB) (2016). Population. Available from https://data.worldbank.org/indicator/SP.POP.TOTL
2. Izzo M, Aucelli PPC, Maratea A, Méndez R, Pérez C, Rosskopf CM, Segura H. A new climatic map of the Dominican Republic based on the Thornthwaite classification. PhysicalGeography, 32(5), 455-472. (2010)
3. Sistema de Información Energética Nacional (SIEN) (2017). Available from https://www.cne.gob.do/servicio/informacion-energetica-sien/
4. Organismo Coordinador del Sistema Eléctrico Nacional Interconectado de la República Dominicana (OCSENI), Informe Anual de Operaciones y Transacciones Económicas año 2016, (2017)
5. Ministerio de Economía, Planificación y Desarrollo (MEPyD), Plan Nacional Plurianual del Sector Público 2017-2020, (2017)
6. International Energy Agency (IEA) (2017). Access to electricity. Available from https://www.iea.org/sdg/electricity/
7. World Economic Forum, The Global Competitiveness Report 2017-2018, (2017)
8. Corporación Dominicana de Empresas Eléctricas Estatales (CDEEE) (2017). Estadisticas institucionales. Available from https://cdeee.gob.do/transparencia/estadisticas-institucionales/
9. Comisión Nacional de Energía (CNE), Prospectiva de la Demanda de Energía de la República Dominicana 2010-2030, (2014)
10. Programa de las Naciones Unidas para el Desarrollo (PNUD), Desarrollo humano, una cuestión de poder. Informe sobre desarrollo humano, República Dominicana 2008, (2008)
11. WorldEconomicForum (WEF), The Global Energy Architecture Performance IndexReport 2014, (2013)
12. Empresa de Generación Hidroeléctrica Dominicana (EGEHID), OfficialWebsite, (2015) Available from: http://www.hidroelectrica.gob.do/
13. Sánchez A, Izzo M, Micro hydropower: an alternative for climate change mitigation, adaptation, and development of marginalized local communities in Hispaniola Island. Climatic Change, 140(1), 79-87. doi:10.1007/s10584-016-1865-0
14. PPS-SGP, Official Website, (2015) Available from: www.ppsdom.org
15. Programa de Pequeños Subsidios (PPS-SGP), Evaluación de impactos en proyectos microhidroeléctricos comunitarios apoyados por el PPS/FMAM de la República Dominicana: los casos de Angostura, Paso de la Perra y Los Calabazos, (2011)
16. Programa de Pequeños Subsidios (PPS-SGP), Evaluación de impactos en proyectos microhidroeléctricos comunitarios apoyados por el PPS/FMAM de la República Dominicana: los casos de La Majagua, Fondo Grande, El Recodo, y El Dulce, (2012)
17. Combariza Díaz NC, Evaluation of Micro Hydro Rural Electrification Projects in the Dominican Republic, MSc Thesis, (2015)
18. UERS, Official Website, (2015) Available from: www.uers.gov.do
19. IAF, Official Website, (2015) Available from: www.iaf.gov
20. Guakia Ambiente, Official Website, (2015) Available from: www.guakiambiente.org
21. Government of the Dominican Republic, Article 110 of the Application Rule of the Law 57-07, (2008)
22. Oficina Nacional de Estadistica (ONE) (2010). Censo de Poblacion y Vivienda 2010. Santo Domingo.
23. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
24. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
25. Alliance for Rural Electrification (2017). Access to Energy Services through Renewable Sources in Latin America & the Caribbean. Available from https://www.ruralelec.org/sites/default/files/2018-01-16_are_best_practices_latam.pdf

2.1.4 Grenada

Sven Homscheid-Carstens, Hydropower Consultant

Key facts

Population	107,825[1]
Area	345 km^2, including the islands of Grenada, Carriacou and Petite Martinique.
Climate	Grenada has a tropical climate, with temperatures around 26 °C and little variation over the year. Daytime temperatures vary between 26 °C and 32 °C, while at night temperatures drop to between 19 °C and 24 °C.[2]
Topography	The terrain is made up of lush green vegetation on steep slopes of volcanic origin. The highest mountain is Mount Saint Catherine, at a height of 840 metres. Average elevation ranges from 300 to 600 metres above sea level.[2]
Rain pattern	Average precipitation is 1,500 mm, peaking at 4,000 mm. The greatest monthly totals are recorded throughout Grenada from June through November, the months when tropical storms and hurricanes are most likely to occur.[2]
Hydrology	The majority of the rivers are located in the centre and north of the island. The upper reaches of some rivers can overflow and cause flooding, while the lower reaches of the rivers can be slow. The largest lake, which was formed in a volcanic crater, is Grand Etang.[2]

Electricity sector overview

Grenada has an electrification rate of 92.3 per cent.[3] By the end of 2017, the country's installed capacity was 50.87 MW, comprising diesel at 48.71 MW (96 per cent) and renewable energy (solar and wind power) at 2.16 MW (4 per cent) (Figure 1).[4] There were no hydropower plants in operation. Peak electricity demand was 32 MW, and annual electricity generation was the highest on record at 223.2 GWh, of which 1.4 GWh was generated by private solar photovoltaics (PV) customers.[4]

Figure 1.
Installed electricity capacity by source in Grenada (MW)

Source: GRENLEC[4]

Other renewable energy sources are currently not contributing to the energy mix. There were plans for Carriacou to build a high penetration diesel and wind hybrid system to power the island, but the first tendering resulted in exorbitant prices and stalling of the project.[5,6]

Transmission voltage level is 33 kV, while distribution voltage level is 11 kV. System losses in 2017 were relatively low at 8.12 per cent.[4] In 2017-2018, measures were taken to improve the efficiency and reliability of the distribution network and generation units. Nonetheless, in 2017 the country experienced challenges with two major generation units in Grenada and a failure in Carriacou, which led to a number of outages.[4]

The sole electricity utility, Grenada Electricity Services Limited (GRENLEC), is 50 per cent owned by a private company from the USA, 21 per cent by the Government of Grenada and the National Insurance Scheme and 29 per cent owned by other private entities, including the company employees.[7] The Electricity Supply Act of 1994 did not allow any other entity but GRENLEC to generate, distribute or sell electricity in Grenada, while GRENLEC could authorize third party electricity generation.[8,9] However in 2016 the Act was replaced by the new Electricity Supply Act No. 19, which ended the monopoly of GRENLEC and opened the electricity sector to other entities. The exclusive electricity generation licence of GRENLEC was replaced with a non-exclusive one, while the transmission and distribution licence was grandfathered under the new act. Through the new legislation the sector was opened to domestic and foreign investment in new projects for the generation of electricity from renewable energy sources.[9]

Furthermore, the private sector participates in the market through privately owned solar PV systems that are connected to the grid under either a net-metering or a net-billing agreement with the utility. Under the new Electricity Supply Act the utility company is obliged to integrate renewable energy generators into the grid.[9]

There is de facto no sector regulator at present, although the new Public Utilities Regulatory Commission Act (PURCA) enacted in 2016 foresees a regulatory commission.[10] The reform of the electricity legislation that is currently underway seeks to introduce a new regulatory regime with the aim to shift electricity generation towards renewable energy use and lower electricity rates for consumers. In March 2011, the Government of Grenada passed a National Energy Policy with the aim of providing 20 per cent of its energy use from renewable energy sources by 2020.[11]

The electricity tariff rates, depending on the type of consumption, comprise a horsepower charge, a floor area charge, a non-fuel charge, a fuel charge, an environmental levy and a value added tax (VAT). The fuel surcharge is calculated monthly based on a running three-month average basis. The base rate was last modified in August 2016 based on the consumer price index.[5,12] Electricity tariffs are structured in different classes for domestic, commercial, industrial and street lighting (Government) customers. As of December 2018, the fuel charge for domestic customers was XCD 0.50 (US$0.19) per kWh and the non-fuel charge was XCD 0.41 (US$0.15) per kWh.[12]

Owners of the renewable energy-based generators selling electricity to GRENLEC are remunerated either at a fixed rate of XCD 0.45 (US$0.17) per kWh or at a variable rate equal to the average fuel price per kWh of the previous year.[12] Both arrangements are valid for a ten-year period.[5]

Small hydropower sector overview

While there is no local definition of small hydropower (SHP), this report assumes the definition of installed capacity up to 10 MW. Installed capacity of SHP in Grenada is 0 MW, the potential capacity is approximately 7 MW.[5] Between the *World Small Hydropower Development Report* (*WSHPDR*) *2016* and *WSHPDR 2019*, installed and potential capacity has not changed (Figure 2).

Figure 2.
Small hydropower capacities 2013/2016/2019 in Grenada (MW)

Source: *WSHPDR 2016*,[5] *WSHPDR 2013*[13]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019.*

In the past, sugar cane estates used hydro wheels to operate mills, but none of these early hydropower stations are in operation today. Several studies have been undertaken to assess the hydropower potential. An analysis carried out in 1981 by the French firm SCET concluded that Grenada has a cumulative potential of at least 7 MW. In 1984, six potential hydropower projects were analysed in a pre-feasibility study at the Great, Marquis and St. Mark's Rivers. In 1991, the British consulting firm MRM Partnership confirmed the hydropower potential of the Great River Upper Basin, including the 720 kW Birchgrove and the 380 kW Belvidere hydropower projects. To date, none of the identified sites have been developed.[5,13]

There are no explicit support mechanisms for hydropower development in the country other than the general preference for the renewable energy-based electricity generation stipulated in the Energy Supply Act.[9] In 2011, the Government of Grenada passed a National Energy Policy, which encourages the use of renewable energy resources with a particular focus on geothermal energy. However, the Policy does not explicitly mention hydropower. Hydropower generation falls under the interconnection rules for renewable energy generation stipulated in the Energy Supply Act and the Public Utilities Regulatory Commission Act.[9,10]

There are no special financing mechanisms in place for renewable energy equipment or projects in Grenada. The Caribbean Development Bank set up a renewable energy and energy efficiency section that seeks to foster increased lending in renewable energy and energy efficiency projects.[5] Several international donor projects, for example, the GIZ and World Bank, can be approached for assistance to identify suitable project financing for larger projects.[5]

Renewable energy policy

The National Energy Policy, dated November 2011, states the country's goal to generate 20 per cent of its energy supply from the renewable sources for domestic energy use (electricity and transport). The policy further elevates the overall importance of the renewable energy for the country's development path. Special reference is made to geothermal resources. However, hydropower is not mentioned specifically.[5,11]

The national power company, GRENLEC, allowed private owners of small solar PV systems to connect to the public grid on a net-metering agreement up to a total of 300 kW cumulative installed PV capacities. This cap was reached in 2014. Since June 2015, GRENLEC has changed the modus to net-billing. This is the current feed-in tariff (FIT) that GRENLEC grants, which is oriented at the avoided fuel cost, but it is not yet regulated by an official entity and may be changed any time.[5]

In January 2017, GRENLEC launched the fourth phase of the interconnection programme with a 1 MW offering, which reserved 300 kW for smaller systems up to 30 kW and 700 kW for larger systems. The 700 kW allocation was fully subscribed with seven 100 kW systems and the 300 kW allocation was fully subscribed with 21 applications. As of early 2018, only ten smaller projects have been commissioned.[4]

Barriers to small hydropower development

The key barriers to SHP development in Grenada include:

- The national focus being on geothermal and solar resources, with a secondary focus on wind power, while hydropower does not play any role in the country's energy supply planning
- No incentives or other special framework conditions for hydropower development have been created
- The country's hydropower potential is poorly investigated
- The processes and procedures for hydropower development are not clearly defined and thus pose a special risk.

References

1. World Bank (2017). *Population, total.* Available from http://data.worldbank.org
2. United States Library of Congress (1987). *Caribbean Islands: A Country Study*. Available from www.countrystudies.us
3. World Bank (2016). *Access to electricity (% of population).* Available from https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS
4. Grenada Services Ltd. (GRENLEC) (2018). *Annual Report 2017.* Available from
5. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
6. Grenada Services Ltd. (GRENLEC) (2014). *Carriacou Wind Project Moving Ahead.* Available from http://grenlec.com/Blog/TabId/126/ArtMID/657/ArticleID/21/Carriacou-Wind-Project-Moving-Ahead.aspx
7. Grenada Services Ltd. (GRENLEC) (n.d.). *Profile.* Available from http://grenlec.com/OurCompany/Profile.aspx
8. Grenada Services Ltd. (GRENLEC) (2015). *Reform of the Grenada electricity sector.* Available from http://www.grenlec.com/Portals/0/Grenada%20Electricity%20Supply%20Act%20and%20Public%20Utilities%20Regulatory%20Commission%20Act%20-%204357741%20v2%20FHBOS.pdf
9. Government of Grenada (2016). *Energy Supply Act (Act No. 19/2016)*, 8 July 2016
10. Government of Grenada (2016). *Public Utilities Regulatory Commission Act (Act No. 20/2016)*, 8 July 2016
11. Government of Grenada (2011). *The National Energy Policy for Grenada.* Available from http://www.gov.gd/egov/docs/other/GNEP_Final_Nov_23_2011.pdf
12. Grenada Services Ltd. (GRENLEC) (n.d.). *Bill Calculator.* Available from http://grenlec.com/YourEnergy/Rates.aspx
13. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013.* United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org

2.1.5 Guadeloupe

International Center on Small Hydro Power (ICSHP)

Key facts

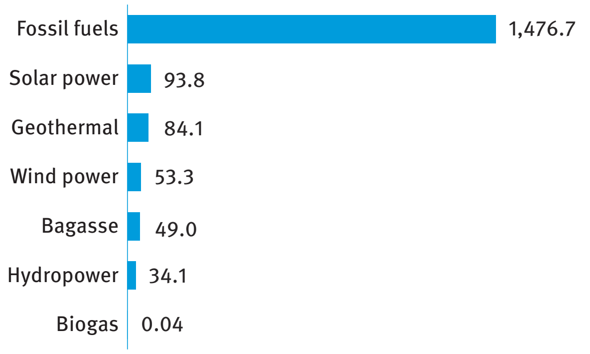
Population	449,246[1]
Area	1,705 km^2 [1]
Climate	The climate is tropical, characterized by humidity and high temperatures all year round. Remarkable stability is observed in monthly temperatures, which may be attributed to *Les Alizés*, the tradewinds. There are two main and distinct seasons in Guadeloupe. The rainy season is between June and November, while the dry season commences in December and ends in May. Inland and coastal areas' average temperatures only differ by a few degrees Celsius. They are between 19 °C and 27 °C in inland areas, while on the coast there is a slight increase, temperatures reach 22 °C to 30 °C. The region is affected by hurricanes that most frequently occur in September, but also anytime during the rainy season, between June and November.[2]
Topography	Comprised of the two main islands of Basse-Terre and Grande-Terre, Guadeloupe is an archipelago that also includes multiple smaller islands. Its location in the eastern Caribbean Sea positively influences the stunning tropical scenery, the beautiful black or white sand beaches and the extravagant mountainous areas. The two main islands are joined together only by a few bridges on a narrow sea channel and a mangrove swamp. Guadeloupe is characterized by volcanic relief, with its highest point measuring 1,467 metres on the Soufriere Volcano.[3]
Rain pattern	The average annual precipitation is 1,814 mm. Rainstorms pass very quickly in general and rain showers are likely to occur at any time during the year, not only between June and November. September is considered the wettest month, while February was historically the driest.[4]
Hydrology	The Basse-Terre island national park is the main source of water in Guadeloupe. Most of its rivers are located here.[5] Some of the more important rivers in Basse-Terre are the Lézarde Rivière, Moustique Rivière, Rose Rivière and Petite Rivière à Goyaves. Canal Perrin and Rivière des Coudes are located on Grande-Terre. Grande Terre and Basse-Terre are separated by Rivière Salée or the Salt River. Nearby small islands and the dry regions of Grande-Terre are supplied with water due to the developed storage capacities and tapped resources.[6]

Electricity sector overview

According to the most recent energy report published by the French Government, total electricity generation in Guadeloupe was 1,791 GWh in 2016.[8] Most of the electricity was generated from fossil fuels such as diesel and coal. Only approximately 18 per cent was from renewable energy sources, with 49 GWh produced from bagasse, 34.1 GWh from hydropower, 53.3 GWh from wind power, 93.8 GWh from solar power, 84.1 GWh from geothermal power and 0.04 GWh from biogas. The remaining 1,476.7 GWh was generated from fossil fuels (Figure 1). The consumption of electricity in 2016 was 1,556 GWh.[8]

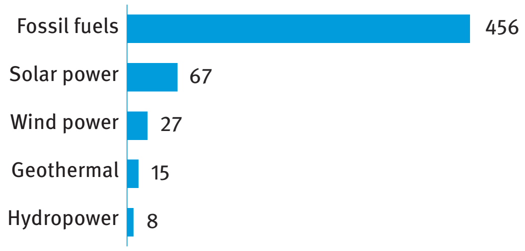
According to 2015 UN data, the total installed electricity capacity in Guadeloupe was 573 MW, with 456 MW from fossil fuels and 117 from renewable energy sources. Figure 2 shows the installed electricity capacity in Guadeloupe by source.[7]

Figure 1.
Annual electricity generation by source in Guadeloupe (GWh)



Source: Guadeloupe Sustainable Development Ministry[8]

Figure 2.
Installed electricity capacity by source in Guadeloupe (MW)



Source: UN data[7]

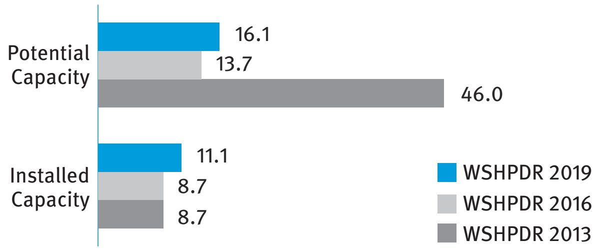
There are two types of utility rates for Guadeloupe: the blue tariff and the green tariff. The blue tariff is for low voltage power supply between 3 and 36 kV and accounts for supply up to 250 kV. The green tariff is for power supply of 250 kV and above. *Electricité de France* (EDF) 2018 statistics estimate the blue tariff at 0.23 US$/kWh and the green tariff at 0.21 US$/kWh. The overall utility rates in Guadeloupe are roughly 0.22 US$/kWh and continue to remain below the Caribbean regional average of 0.33 US$/kWh. These low rates are a result of existent French electricity regulations which maintain equal prices across mainland and overseas territories.[9]

Small hydropower sector overview

The installed capacity of small hydropower (SHP) in Guadeloupe is 11.1 MW, which produced 34 GWh of electricity in 2016. In comparison to 27 GWh in 2013, production has increased by 7 GWh due to the new hydropower plant, Goyave, which was installed in 2016.[11,13] Basse-Terre is the centre for the existing hydropower activity, due to the resources available and its favourable topography. The new hydropower plant installed in 2016 is also located in Basse-Terre, in the commune named Goyave. On Grande-Terre there are only the hydropower plants of Letaye and Gaschet.[11] Most plants are operated by plants are operated by Force Hydraulique Antillaise (FHA). The FHA ensures energy-saving and contributes to sustainable development in Guadeloupe since 1999 and has constructed and operated 13 SHP plants.[13,14] Table 1 below offers detailed information on the small hydropower plants in Guadeloupe and their installed capacity.

The *World Small Hydropower Development Report (WSHPDR) 2019* estimates the country's SHP potential at the minimum of 16.1 MW, based on the feasibility studies carried out at Riviere du Gailon (1.5 MW) and Capesterre (3.5 MW). The installation of these two plants is still planned at present.[11,16] In order to achieve energy autonomy, the Government of Guadeloupe officially expressed its intention to increase the hydropower share in the country's energy mix up to 2 per cent by 2030, from the current 1.3 per cent. However, the most recent energy report made available does not have any new data with regards to hydropower potential in Guadeloupe. The newest projects planned for the further development of electricity generated from renewable energy sources only focus on exploiting solar power, wind power, bagasse and geothermic sources.[13,15]

Figure 3.
Small hydropower capacities 2013/2016/2019 in Guadeloupe (MW)



Source: *WSHPDR 2013*,[10] *WSHPDR 2016*,[11] EDF[13]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

Table 1.
Installed small hydropower capacity in Guadeloupe

Site name	*Owner*	*Installation year*	*Installed capacity (MW)*
Carbet	EDF	1993	3.5
Goyave	FHA	2016	2.4
Bananier amont	EDF	1994	1.2
Bananier aval	EDF	1994	1.8
Partiteur 1 & 2	FHA	1995	0.5
Gaschet	FHA	2002	0.2
Letaye	FHA	2002	0.2
Bellevue	FHA	2002	0.1
Clairefontaine	FHA	2002	0.2
Saint Sauveur	FHA	2003	0.07
Schoeler	FHA	2004	0.07
Le Bouchu	FHA	2004	0.2
Dole	FHA	2004	0.2
Valeau	FHA	2006	0.2
Bovis	FHA	2008	0.25

Source: *WSHPDR 2016*,[11] EDF[13]

Note: Data as of 2016.

Renewable energy policy

Guadeloupe aims to achieve sustainable development and energy autonomy through its Regional Plan for Renewable Energy and the Rational Use of Energy (PRERURE). The plan was officially announced in 2007 and updated in 2012. One of the notable goals of PRERURE is to achieve 50 per cent of all primary energy from renewable energy sources by 2030.[9,11] The local government has already made attempts to accomplish the aforementioned goal. A capacity of 60 MW of renewables is planned to be installed by 2025, to meet additional needs identified after 2023. There is an undergoing project that uses biogas to add 10 more MW to the already existent installed capacity in the Gabarre site. In addition, two wind power plants are under construction. One project is located in Marie-Galante (4 MW) and the other in the North of Guadeloupe (7 MW). A new geothermal plant of 10 MW capacity will be completed in 2020. On December 16, 2016, the authorities announced a call for 50 MW solar project proposals. This could lead to the installation of several solar plants in the region.[13]

In the research and development (R&D) sector, there are also notable achievements. The Government of Guadeloupe considerably improved energy calculation of buildings by issuing a new, innovative software. Off-vehicle charging and electricity generation from sugar cane fibres represent technologies that contributed actively to the sustainable development of the region.[11,12] The effective implementation of future renewable energy projects also depends on reducing project-associated costs and attracting investment.

Barriers to small hydropower development

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

- Environmental standards imposed are strict and the construction of new SHP plants may be slow to ensure compliance
- Important water resources for micro- and small hydropower are located in the National Park, which is a protected area
- High costs for grid connection and areas clearing represents another significant barrier
- There is more interest in the development of other renewable energy source, rather than small hydropower, as after multiple feasibility studies, it was concluded solar, geothermal and wind power are most cost-effective alternatives.[11,13]

References

1. United Nations Data (2017). General Information: Guadeloupe. Available from www.data.un.org
2. French Caribbean International (n.d.). *Weather, Climate.* Available from http://www.frenchcaribbean.com/Guadeloupe/Helpful-Info/Climate-Weather/. Accessed on April 2018
3. World Travel Guide (n.d.). *Guadeloupe weather, climate and geography.* Available from http://www.worldtravelguide.net/guadeloupe/weather-climate-geography. Accessed on April 2018
4. Climatemps (n.d.). *Pointe-À-Pitre* Climate & Temperature. Available from http://www.guadeloupe.climatemps.com/. Accessed on April 2018
5. Parc National de la Gudeloupe (n.d.). *Eau douce: Cascades et rivières.* Available from http://www.guadeloupe-parcnational.fr/?Eau-douce-Cascades-et-rivieres. Accessed on April 2018
6. Pouget, J. C. and Dezetter, A. (1993). Water resources management in a tropical island environment. The case of Guadeloupe. *Hydrology of Warm Humid Regions*. International Association of Hydrological Sciences (IAHS) Publ. no. 216, 1993.
7. UN data (2015). Electricity- total net installed capacity of electric power plants: Guadeloupe. Energy Statistics Database. Available from http://www.data.un.org
8. French Ministry for Sustainable Development (2017). Erratum Publication energie – bilan 2016. Guadeloupe Energie. Available from http://www.guadeloupe.developpement-durable.gouv.fr/IMG/pdf/erratum_publication_energie_bilan_2016.pdf
9. Electricite de France (EDF) (2018). Les tarifs d'EDF. EDF Guadeloupe. Available from https://www.edf.gp/
10. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
11. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
12. European Commission (2014). *Guadeloupe Strategy 2020 Action plan for the region of Guadeloupe for the programming of European Funds 2014-2020.* Available from http://caribbean.cepal.org/content/guadeloupe-strategy-2020.
13. Électricité de France (EDF) (2017). *Systemes Energetiques Insulaires Guadeloupe*. Available from https://www.edf.gp/sites/default/files/SEI/producteurs/guadeloupe/edf_sei_bp2017_guadeloupe.pdf
14. Force Hydraulique Antillaise (n.d*.). Energies Renouvelables.* Available from http://www.forcehydraulique.com/.
15. Guadeloupe Energie (n.d.). *Vers l'autonomie* énergétique *de la Guadeloupe.* Available from http://www.guadeloupe-energie.gp/politique-energetique/strategie-regionale-2/vers-lautonomie-energetique-de-la-guadeloupe. Accessed on April 2018
16. Environment and Energy Management Agency, France (ADEME) (2012). *Schema Regional Climat Air Enerie. SRCAE de Guadeloupe.* Available from http://www.guadeloupe.developpement-durable.gouv.fr/IMG/pdf/f10g_SRCAE_2012_263p.pdf.

2.1.6 Haiti

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

Key facts

Population	10,981,229[1]
Area	27,750 km[2]
Climate	Haiti has a warm, humid, tropical climate. Average temperatures range from 25 °C in January and February to 30 °C in July and August. There is also significant variation in temperatures with altitude. Thus, the average temperature in the village of Kenscoff lying at 1,430 metres is 16 °C, while in Port-au-Prince lying at sea level the average temperature is 26 °C. In winter months, frost can occur at high elevations.[2]
Topography	The country occupies the western third of Hispaniola island and a number of smaller islands, such as La Gonâve, La Tortue, Grosse Cayes, Les Cayemites and Ile-a-Vache. The relief of Hispaniola is predominantly rugged in the centre and in the west, with approximately two-thirds of the territory lying at elevations above 490 metres. The coastline is irregular with generally rocky shores rimmed with cliffs. There are four major mountain ranges extending from west to east: the Northern Massif, the Matheux Mountains (or the Trou d'Eau Mountains), the Massif de la Hotte and the Massif de la Selle. The country's highest peak, Mount La Selle, reaches 2,674 metres. An area of approximately 390 km^2 in the interior is occupied by the Central Plateau, which has an average elevation of 300 metres. With a long fault line crossing the southern part of the country and passing just south of the capital city Port-au-Prince, the country is subject to periodic seismic activity.[2]
Rain pattern	The northern and eastern slopes of the mountains tend to experience higher humidity, while some parts of the island receive less than 700 mm of rainfall per year. The smallest amounts of precipitation are received in the north-western peninsular and La Gonâve Island. Some regions of the country have two rainy seasons lasting from April to June and from August to October, while other regions receive rain from May to November. In general, annual precipitation ranges from 400 mm to 1,000 mm.[2]
Hydrology	The River Artibonite is the longest river on the island at 280 km. It rises in the Northern Massif (the Cordillera Central) in the western Dominican Republic and flows south-westwards along the border with Haiti, draining into the Gulf of La Gonâve. Its tributaries flow eastwards and southwards through the Central Plateau. In the east, the Artibonite was impounded as Lake Péligre. Most other rivers are short and not navigable.[2]

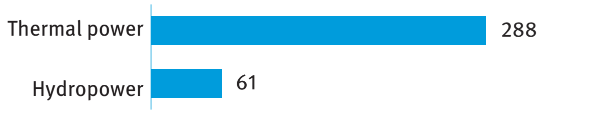
Electricity sector overview

As of 2018, the total installed capacity of all power plants connected to the grid in Haiti was 349 MW, of which approximately 70.6 per cent was from thermal power plants and 29.4 per cent from hydropower plants (Figure 1).[3] The available capacity of the operational plants is, however, considerably lower – at approximately 253 MW.[3]

Electricity in Haiti is generated by the state-owned company Electricité d'Haiti (EDH) and Independent Power Producers (IPPs). The major power plants (the hydropower plant Péligre, and thermal plants Carrefour I, Carrefour II, Varreux and Epower) account for 250 MW of installed capacity supply electricity to the metropolitan area of Port-au-Prince. With Péligre freshly rehabilitated, the available capacity in the area increased to 183.36 MW, of which 39 per cent are operated by EDH, 47 per cent by an IPP and the remaining 14 per cent by Carrefour II, which is a tripartite operation financed under the umbrella of the Petrocaribe programme.[3] In the provinces, there are multiple thermal and hydropower plants of smaller capacity operated by EDH either directly or in the modality of a semi-autonomous centre. The combined installed capacity in the provinces is approximately 98 MW, of which approximately 70 per cent is available, including the 10 MW thermal power plant of Caracol operated by NRECA.[3]

The demand in the country significantly exceeds the available capacity, and a large number of big consumers (hotels, factories, embassies) choose to produce their own electricity using diesel units or contract electricity generation. The total capacity of the self-producers is estimated to be at least 500 MW according to a small survey undertaken in 2017.[3] The country's hydropower installed capacity is approximately 61 MW, of which almost 58 MW is available following the refurbishment of the Péligre hydropower plant in 2018.[3]

Figure 1.
Installed electricity capacity by source in Haiti (MW)



Source: IDB[3]

Note: The data include only on-grid capacities.

Total electricity generation in 2017 was 1,089 GWh, of which thermal power accounted for 88 per cent and hydropower for the remaining 12 per cent (Figure 2). Over 82 per cent of total generation came from power plants located in Port-au-Prince area, where the country's almost all economic activities are concentrated.[4,5]

Figure 2.
Annual electricity generation by source in Haiti (GWh)

Source: EDH[4]

Note: The data include only on-grid capacities.

In 2016, only 39 per cent of the population across the country had access to electricity.[6] The electricity grid in Haiti consists of a number of isolated grids. Outside of the metropolitan area, there are ten regional grids, which are operated by EDH and serve the larger towns and nearby areas, as well as approximately 30 village-level grids. However, even communities connected to the grid do not receive reliable electricity service and experience frequent outages.[8] It is estimated that EDH officially serves 270,000 customers, i.e. users legally connected to the grid, but there are also many more unofficial users who are connected to the grid illegally.[7]

By a decree of 20 August 1989 EDH was granted monopoly rights to generate, transmit, distribute and sell electricity across the country, however, the same decree also allowed EDH to outsource electricity production to IPPs. Another decree issued in 2006 allowed local communities not served by EDH to contract independent enterprises to provide electricity services, which fostered the development of micro-grids in the country. Historically there was no regulatory agency overseeing EDH activities. However in 2016 the National Authority for the Regulation of the Electricity Sector (ANARSE) was established, whose purpose is to guide the development of the electricity sector, in particular, through increasing the private sector involvement.[8]

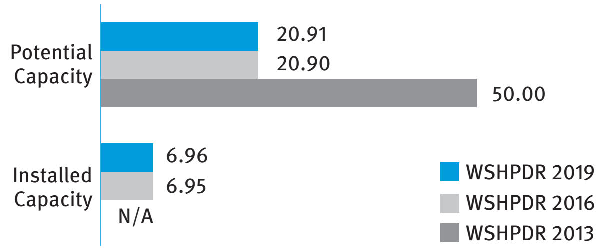
Electricity tariffs for residential consumers range from 4.80 HTG/kWh (0.07 US$/kWh) to 12.74 HTG/kWh (0.18 US$/kWh) in the metropolitan area and from 6.90 HTG/kWh (0.10 US$/kWh) to 12.74 HTG/kWh (0.18 US$/kWh) in the provinces, and depend on the amount of electricity consumed.[9]

Small hydropower sector overview

There is no official definition of small hydropower (SHP) in Haiti. However, the Ministry of Public Works, Transport and Communications (MTPTC) gave a definition of SHP as plants with a capacity of 1 MW to 10 MW in the outline of the Expression of Interest to Participate in the Scaling Up Renewable Energy in Low Income Countries Program (SREP). Micro- and pico-hydropower were defined as plants with a capacity of 0.1 MW to 1 MW and less than 0.1 MW, respectively.[5] For the purposes of this report, all hydropower plants up to 10 MW will be classified as small hydropower.

In 2018, the total installed SHP capacity up to 10 MW in Haiti was 6.96 MW, while the available capacity was 3.7 MW (Table 1).[3] The untapped SHP potential is estimated at 13.95 MW.[5] Compared to the results of *the World Small Hydropower Development Report (WSHPDR) 2016*, installed capacity increased by 11 kW (Figure 3).

Figure 3.
Small hydropower capacities 2013/2016/2019 in Haiti (MW)



Source: IDB,[3] *WSHPDR 2016*,[5] *WSHPDR 2013*[10]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2016.*

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

Over the years, the available capacity of the hydropower plants has decreased almost two-fold due to ageing equipment and a lack of maintenance. In July 2018, with more than US$100 million provided by the Inter-American Development Bank, the KfW Development bank and the OPEC Fund for International Development, the biggest source of renewable energy in the country, the Péligre hydropower plant, regained its initial capacity of 54 MW.[5,11]

Table 1.
Small hydropower plants in Haiti (MW)

Region	*Site name*	*Installed capacity (MW)*	*Available capacity (MW)*
Le Grand Nord	Caracol	0.80	0.50
	Drouet	2.15	0.50
	Délugé	1.10	0.50
Le Grand Sud	Saut Mathurine	1.60	1.40
	Gaillard	0.50	0.30
Centre Ouest	Onde-Verte	0.80	0.50
Nord-Est	Magazen	0.01	0.01
Total		**6.96**	**3.71**

Source: IDB[3]

In addition to the existing hydropower capacities, there is a significant hydropower potential that can be harnessed. According to the most recent estimate by EDH, there are 23 potential hydropower sites ranging in capacity from 0.23 MW to 90 MW and with a combined untapped potential of 298.95 MW (Table 2).[5]

Table 2.
Potential hydropower sites in Haiti

Name	*Location*	*Capacity (MW)*
Dos Bocas	HAI/DR Border	90.00
Guyamouc	HAI/DR Border	22.00
Guayamouc	Thomonde El Baye	34.00
Guayamouc	Thomassique	21.00
Art 1	Verettes	32.00
Art 2	Deschapelles	56.00
Art 4C	Mirebalais	30.00
La Thème	Mirebalais	0.67
Pichon 1	Belle Anse	0.40
Pichon 2	Belle Anse	0.68
Casales 1	Casales	0.89
Casales 2	Casales	0.47
Samana	Samana	0.78
Bassin Bleu	Bassin Bleu	0.43
Ti Letang	La Vallee de Jacmel	1.40
Voldrogue	Voldrogue	0.23
Saut du Baril	Saut du Baril	0.37
3 Rivières	Trois Rivières	1.18
3 Rivières	Trois Rivières	0.73
GA-4.2	Grande Anse	1.21
GA-35.4	Grande Anse	0.97
GA /BD-8.6	Grande Anse	1.06
GA/BD-15.4	Grande Anse	2.48
Total		**298.95**

Source: EDH[12]

Renewable energy policy

The development of the country's energy sector follows the Strategic National Plan for the Development of Haiti (SPDH), which envisages improving on-grid electricity services in urban areas and surroundings and supporting off-grid electrification in rural areas. The most recent National Development Plan for the Energy Sector (2007-2017) recommends the promotion of renewable energy sources (wind power, solar power, biofuels) and the creation of an additional capacity from renewable energy sources of some 40 MW.[13] However, the 2010 earthquake, which damaged or destroyed a great number of electricity facilities, rendered the plan out-of-date, and it has not been updated yet.

Nonetheless, the Government remains committed to the development of renewable energy sources in the country. In the 2017-2018 budget, measures for the promotion of renewable energy projects, particularly solar power, were introduced, including the elimination of import tariffs and duties on solar equipment. One of the objectives for the 2017-2018 fiscal year was to pursue the installation of solar power facilities across the country, particularly in areas with limited infrastructure, with a minimum of one installation per community.[14]

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

- Improve the environment for private investment in renewable energy
- Expand the access for rural households through leveraged investments in micro- and mini-grids, and village level systems
- Strengthen the capacity of local institutions and develop awareness of local communities on how to use renewable energy
- Finance private operators, non-governmental and community organizations to provide solar lanterns, and individual and home-based solar systems.[15]

Barriers to small hydropower development

The barriers hindering the development of SHP in Haiti include:

- Absence of a single decision-making authority and lack of coordination among Government agencies and ministries
- Absence of a legal framework aiming to facilitate private investment and technical rules facilitating connection between local grids
- Limited funds for the construction of hydropower plants. The initial investment for the construction of a plant is considerably high, therefore, developers can be reluctant to invest

- Limited data on the identified potential sites. Data need to be collected on a regular basis and a specific department of engineers with hydropower knowledge should be responsible for their upkeep and dissemination
- High cost of electricity system development.[5,8,16]

References

1. World Bank (2017). *Haiti. Population, total.* Available from https://data.worldbank.org/indicator/SP.POP.TOTL?locations=HT
2. Encyclopaedia Britannica (2018). *Haiti*. Available from https://www.britannica.com/place/Haiti
3. Inter-American Development Bank (IDB) (2018). Internal data
4. Electricité d'Haiti (2018). Budget 2018. Available from http://www.edh.ht/docs/R%C3%A9vision_Budget_2018.pdf
5. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
6. World Bank (2016). *Haiti. Access to electricity (% of population).* Available from https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=HT
7. National Authority for the Regulation of the Electricity Sector (ANARSE) (2018). Appel à pré-qualification de promoteurs (apq) pour la réalisation des travaux de renforcement et d'expansion du réseau électrique d'Haiti. N° 05-02-anarse/2018. Available from http://anarse.gouv.ht/wp-content/uploads/2018/06/APQ-travaux-dexpansion-du-reseau-electrique-national-28mai2018-1.pdf
8. Boston University Institute for Sustainable Energy (2018). *Assessment of Haiti's Electricity Sector.* Available from https://www.bu.edu/ise/files/2018/03/FINAL-Haiti-Electricity-Report-March-2018.pdf
9. Electricité d'Haiti (n.d.). *Tarif.* Available from http://www.edh.ht/tarif.php
10. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
11. Electricité d'Haiti (n.d.). *Réhabilitation de la centrale de Péligre.* Available from http://www.edh.ht/rehabilitation-peligre.php
12. Electricité d'Haiti (2015). Internal documentation.
13. Ministry of Public Works, Transport and Communications (MTPTC) (2006). *Haiti Energy Sector Development Plan 2007-2017.* Available from http://www.bme.gouv.ht/energie/National_Energy_Plan_Haiti_Revised20_12_2006VM.pdf
14. Ministry of Economy and Finance (2017). *Projet de loi de finances 2017-2018.* Available from http://www.haitilibre.com/docs/17_18_projet_de_loi_de_finances.pdfWorld Bank (2017). *World Bank Approves US$35 Million for Clean Energy and Improved Electricity Access in Haiti.* Available from https://www.worldbank.org/en/news/press-release/2017/10/26/world-bank-approves-us35-million-for-clean-energy-and-improved-electricity-access-in-haitiClimate Fund (2014). *Terms of Reference, Scaling-up Renewable Energy Program (SREP), Scoping Mission.* Available from http://www.climateinvestmentfunds.org/cif/sites/climateinvestmentfunds.org/files/TOR_SREP%20Haiti%20Scoping%20Mission_Oct%202014-final.pdf

2.1.7 Jamaica

Patricia Lewin, National Commission on Science and Technology (NCST); Betsy Bandy and Mark Williams, Ministry of Science, Technology, Energy and Mining; and International Center on Small Hydro Power (ICSHP)*

Key facts

Population	2,728,864[1]
Area	10,991 km[2]
Climate	Jamaica has two climatic zones. It is tropical on the windward side of the mountains and semi-arid on the leeward side. Temperatures remain constant throughout the year, averaging 25 °C to 30 °C in the lowlands and 15 °C to 22 °C at higher elevations.[2]
Topography	The terrain is mostly mountainous, with a narrow, discontinuous coastal plain. Blue Mountain Peak is the highest point of the Blue Mountain Range at 2,256 metres above sea level.[2]
Rain pattern	Average annual rainfall is 1,980 mm. Easterly and north-easterly trade winds bring rainfall throughout the year, depositing most of their moisture on the northern slopes of the axial mountain ranges, with the southern half of the island lying in the rain shadow. Island-wide long-term mean annual rainfall exhibits a characteristic pattern, with the primary maximum in October and the secondary in May. The main dry season lasts from December to April.[2]
Hydrology	The central mountain ranges divide the catchment areas for the rivers that drain either to the north or to the south coasts. Surface runoff predominates on outcrops of basement rocks and interior valley alluviums. Perennial rivers, like the Martha Brae River and the White River, have low seasonal flow variability. The Great River and the Blue Mountains basin have varying seasonal flows and low baseflow.[3,4]

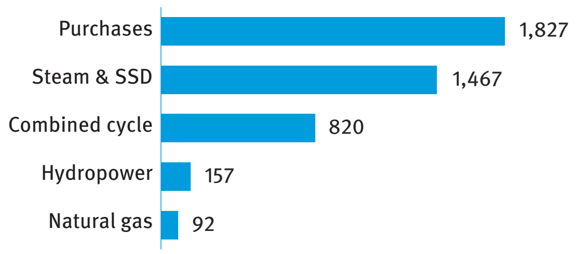
Electricity sector overview

The economy of Jamaica has been chiefly dependent on oil imports, with most of the consumption in the bauxite/alumina, power generation and transportation sectors. Much has been done to diversify its energy consumption with an emphasis on energy security based on domestic renewable energy sources. There is also a thrust to improve the country's energy efficiency and conservation mechanisms.

The electricity generation sector is the country's largest petroleum consumer. Oil and diesel-fired steam generation has a low 29 per cent efficiency rate.[5] Electricity losses on the grid remain high at 26.5 per cent in 2017.[6] These losses are predominantly the result of theft and illegal connections. The National Water Commission is the single largest electricity customer, with electricity costs accounting for nearly 40 per cent of annual revenue.[52]

The Jamaica Public Service Company Limited (JPS) is the country's main electricity provider. According to the JPS 2017 Annual Report, 4,363 GWh of electricity was generated in 2017 (with 1,827 GWh coming from private power purchases), compared to 4,349 GWh in 2016. This increase is attributed to higher than normal temperatures experienced during the summer months. Of electricity produced by JPS, hydropower accounted for 4 per cent, while the rest came from steam, slow speed diesel (SSD), natural gas and combined cycle plants (Figure 1).[6] Though JPS retains a monopoly on the transmission and distribution of electricity, the production regime has been liberalized to include generation of electricity by independent power producers (IPP) for their own use or for sale to the national grid.[7]

Figure 1.
Annual electricity generation by source in Jamaica (GWh)



Source: JPS[6]

The Government has a vested drive to reduce the country's dependency on imported fossil fuels by infusing renewable sources into the country's energy mix. An estimated 11 per cent (491 GWh) of the electrical supply mix was attributable to RE during 2017, compared to 6 per cent in 2014.[6,8] Almost

* *WSHPDR 2016* updated by ICSHP

70 per cent of electricity from renewable energy sources in 2017 was, thus, generated by private power producers. The country's target is to achieve a 30 per cent share of RE in electricity generation by 2030.[6] In early 2018, the available generation capacity of the country stood at 941 MW, of which 144 MW was from RE sources, including 22 MW of hydropower owned by JPS, 3 MW of wind power capacity owned by JPS, 99 MW of wind power capacity owned by IPPs and 20 MW of solar power capacity owned by IPPs.[9] In 2017, a 37 MW solar photovoltaics (PV) power plant was approved for development at Paradise in Westmoreland.[10] In addition the construction of a 190 MW power plant fired by natural gas was launched at Old Harbour Bay and a 94 MW liquefied natural gas (LNG) power plant is to be built in central Jamaica, in order to diversify the country's energy mix.[6]

The Office of Utilities Regulation (OUR), with support from USAID and the National Renewable Energy Laboratory (NREL), completed a study on the Net Billing Programme in 2015. This programme allows individuals and companies to generate their own electricity from renewable energy sources and sell any excess to the electric grid operator under terms of Standard Offer Contracts (SOCs) and the supervision of the OUR. After three years, a review of the programme was completed and renewed efforts are being made to achieve the target of approximately 12 MW, representing 2 per cent of the system peak demand.[8] As of the end of 2017, the capacity connected under the programme stood at 5.8 MW.[6]

According to the Ministry of Science, Energy and Technology (MSET), the Government of Jamaica has taken steps to facilitate the expansion of the RE industry by providing concessions for the following:

- Reduction of import duty from 30 per cent to 5 per cent on all RE equipment
- Zero rating for General Consumption Tax (GCT) purposes on RE equipment
- Payment of a premium of 15 per cent above the current "Avoided Generation Cost" for the procurement of electrical energy from renewable energy sources.[8]

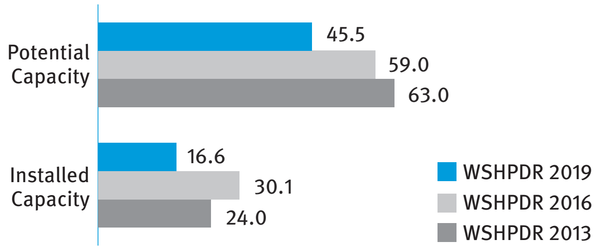
The JPS is regulated by the OUR under an incentive-based framework, known as a price cap regime. This framework was introduced through the 2001 Electricity Licence, and amended in 2011 and 2016.[11] Under this framework, the OUR determines rates in respect of electricity generation, transmission, distribution and supply. Electricity tariffs are reviewed once every five years, but can also be adjusted on an annual basis or in exceptional circumstances. The prices per kWh approved by the OUR for 2018-2019 range from JMD 3.71 (US$0.03) to JMD 24.19 (US$0.19) depending on the type and amount of consumtion.[12]

The electrification rate stands at 98 per cent, with the remaining 2 per cent of houses being located in extremely remote areas. This was made possible through the Rural Electrification Programme (REP), which was recently renamed the National Energy Solutions Limited (NESOL).[13]

Small hydropower sector overview

Small hydropower (SHP) in Jamaica is defined as hydropower plants with an installed capacity between 1 MW and 10 MW. Compared to the *World Small Hydropower Report* (*WSHPDR*) *2016*, the installed and potential capacities decreased due to the exclusion of the Maggoty plant from the calculation of the total (Figure 2).

Figure 2.
Small hydropower capacities 2013/2016/2019 in Jamaica (MW)



Source: *WSHPDR 2016*,[8] MSET,[14] CAPRI,[15] PCJ,[16] *WSHPDR* 2013[17]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019.*

The JPS has eight hydropower plants among its mix of generating units, which contribute approximately 30 MW to the grid.[8,15] It should be noted that the Maggoty plant recently had an extension, which brought its total capacity above the 10 MW upper limit (13.5 MW). Therefore it is not included in the country's SHP total capacity anymore, which stands at 16.6 MW.[15] In addition, there are 11 sites with approximately 29 MW of potential capacity, which have been identified as having potential for hydropower development (Table 1).

Table 1.
Hydropower in Jamaica

Site	*Status*	*Capacity (MW)*	*Production (GWh)*
Rio Bueno A	existing	2.5	13.1
Rio Bueno B	existing	1.1	5.8
Maggoty Falls	extension	13.5*	66.1
Upper White River	existing	3.8	19.9
Lower White River	existing	4.0	21.0
Roaring River	existing	3.8	19.9
Constant Spring	existing	0.8	4.2
Ram's Horn	existing	0.6	3.1
Great River	proposed	8.0	42.0
Laughlands	proposed	2.0	10.5
Back Rio Grande	proposed	28*	52.5
Green River	potential	1.4	7.3
Martha Brae	potential	4.8	36.5
Rio Cobre	potential	1.0	5.2
Dry River	potential	0.8	4.2
Negro River	potential	1	7.5

Site	*Status*	*Capacity (MW)*	*Production (GWh)*
Yallahs River	potential	2.6	13.6
Wild Cane River	potential	2.5	13.1
Morgan's River	potential	2.3	8.1
Spanish River	potential	2.5	18.6

Source: MSET,[14] CAPRI,[15] PCJ[16]

Note: Some feasibility data unavailable. An asterisk (*) denotes larger than SHP (10 MW) capacity

Studies were conducted on the Rio Cobre River in St. Catherine, the Negro River in St. Thomas, Martha Brae River in Trelawny and Spanish River in Portland. This was followed by pre-feasibility studies in 2013, which identified a combined potential of more than 20 MW in generating capacity from these sources. Previous assessments of the Laughlands Great River in Saint Ann and Great River in Saint James could create investment packages for the development of approximately 26 MW in hydropower. If this potential were fully exploited, it would double the country's hydropower generating capacity and produce 95.7 GWh annually, which would reduce the country's oil consumption by more than 56,300 barrels per year, yielding savings of almost US$329 million.[8,15]

Recent assessments conducted by the United Nations Economic Commission for Latin America and the Caribbean to determine the hydropower potential at 11 sites across Jamaica found that most sites demonstrated a potential capacity of some 2.5 MW or more. This amounts to a total untapped potential of 33.4 MW.[8]

Renewable energy policy

Through the MSET the Government of Jamaica has been taking steps towards achieving the vision of the National Energy Policy (NEP). The NEP is aligned with the country's National Development Plan, Vision 2030, and seeks to create a modern, efficient, diversified and environmentally sustainable energy sector, which is expected to facilitate the provision of more affordable energy supplies as well as sustainable growth and development for industries.[7,8]

The National Energy Policy 2009-2030 highlights that energy diversification will involve moving away from an almost total dependence on petroleum to a strategic mix of other sources, including natural gas, coal, petcoke, nuclear and RE such as solar power, wind power, hydropower and biofuels. Notwithstanding, focus is being given to the development of RE sources as a measure to combat the effects of fluctuation in crude oil prices.[7,8]

In June 2014, the Cabinet approved the plans of the Electricity Sector Enterprise Team (ESET) regarding the modernization and diversification of the country's energy infrastructure. The ESET, in consultation with OUR, JPS and MSET, was tasked to manage the procurement process for new electricity generating capacity. Among its mandates were the preparation of an Optimized Integrated Resources Plan, selection of projects for implementation and the development of financing strategies.[8]

The Electricity Act 2015 has a section for Renewable Energy Generation. Additionally, the draft Renewable Energy Policy will be reviewed to clarify and codify the roles and responsibilities of the main actors in the sector, including the Government, the regulator, the utilities and the independent power producers.[8]

The national renewable energy (RE) focus is on the policy goals of:

- Achieving the development of the economic, infrastructural and planning conditions conducive to RE development
- Outlining the financial and fiscal policy instruments needed and the legislative and regulatory environment;
- Implement the All Island Electric Act (2011)
- Developing and promoting RE technologies.[8]

The Government sees hydropower as a relatively viable solution for the country's energy needs. At the moment of writing, the Government is preparing the Integrated Resource Plan (IRP), which is to serve as a roadmap for meeting the country's electricity grid objectives and will include hydropower as an alternate source of renewable energy. The Minister of Science, Energy and Technology has emphasized that a greater focus should be placed on hydropower.[18]

The MSET signed a multimillion dollar contract with the World Bank, for technical assistance towards the promotion and development of cost effective, SHP projects across Jamaica. The country's SHP resources could play a significant role in providing low cost energy to the electric grid, as well as expanding energy access to remote locations. This will involve feasibility studies, assistance and guidance to key agencies in the administration of hydropower development in Jamaica. The agreement is to also support the development and implementation of departmental policies and procedures, for the effective management of hydropower projects from design to operation.[8,19]

The MSET announced that there were several sites where SHP capacity could be harnessed for use, with approximately 15 MW of the total 23 MW of SHP potential in the island being considered firm, while the rest is variable, due to seasonal changes in the stream flow.[8,19] The sites being investigated are the Rio Cobre River (Saint Catherine), Morgan's River and Negro River (Saint Thomas), Martha Brae River (Trelawny) and Spanish River (Portland).[8]

Barriers to small hydropower development

Early studies identified several barriers to the wide scale adoption of RE in Jamaica. These include:

- The limited availability of financing
- Negative views of hydropower
- Absence of or weak fiscal and regulatory provisions

- Absence of appropriate protocol to facilitate contracts governing buyer-seller relationships.[8]

The contribution from renewable sources to the electricity sector are predicted to increase from the current level of 6 per cent up to 15 per cent by 2020. Tax policies will be designed to encourage the development of the RE sector. The Government will strengthen the legislative and regulatory framework and establish appropriate protocols to facilitate the development of the sector and govern trading relationships including a basis for premium pricing.[8]

References

1. Statistical Institute of Jamaica. (2017). *End of Year Population*. Available from http://statinja.gov.jm
2. U.S. Library of Congress (2015). *Country Studies*. Available from http://countrystudies.us/caribbean-islands/20.htm
3. Jamaica, Water Resource Authority (2015). *Exploitable Water*. Available from http://www.wra.gov.jm
4. United Nations Food and Agriculture Organization (2015). *Jamaica, Geography and Climate*. AQUASTA. Available from www.fao.org
5. Jamaica, Ministry of Science, Technology, Energy and Mining (2015). *Overview of Jamaica's Electricity Sector*. Available from http://www.mstem.gov.jm/?q=overview-jamaicas-electricity-sector
6. Jamaica Public Service Company Limited (JPS) (2018). *Annual Report 2017.* Available from https://s26303.pcdn.co/wp-content/uploads/2018/07/JPS-2017-AR.pdf
7. Jamaica, Ministry of Science Technology Energy and Mining (2009). *Jamaica's National Energy Policy 2009-2030: Securing Jamaica's Energy Future, Advancing Competitiveness, Promoting Sustainable Prosperity*. Available from http://mstem.gov.jm/sites/default/files/National%20Energy%20Policy.pdf
8. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
9. Office of Utilities Regulation (OUR) (2018). *Development of Renewable Energy Market in Jamaica: A Regulatory Perspective.* Presentation by Francis, C. at Emerging Regulatory Issues Workshop, 6-7 February 2017
10. Office of Utilities Regulation (OUR) (2017). *Annual Report 2016-2017.* Available from http://www.our.org.jm/ourweb/sites/default/files/documents/business_plan/annual_report_2016-2017_-_pdf.pdf
11. Jamaica Gazette (2016). *Jamaica Public Service Company Limited Electricity Licence 2016*, Vol. CXXXIX, No. 6A. Available from https://www.mset.gov.jm/sites/default/files/pdf/Electricity%20Licence%202016.pdf
12. Jamaica Public Service Company Limited (JPS) (2018). *Annual Review 2018 & Extraordinary Rate Review.* Available from http://www.our.org.jm/ourweb/sites/default/files/documents/sector_documents/jps_2018_annual_review_upload_request.pdf
13. National Energy Solutions Limited (NESOL) (n.d.). *Who we are.* Available from https://www.nesol.gov.jm/who-we-are/
14. Jamaica, The Ministry of Science, Energy and Technology (MSET) (2013). *Grid impact analysis and assessments for increased penetration of renewable energy into the Jamaica electricity grid, Final report.* Available from http://mstem.gov.jm/sites/default/files/pdf/Grid%20Impact%20Analysis%20Final%20Report_0.pdf
15. Caribbean Policy Research Institute (CAPRI) (2015). *Country Stakeholders Report Jamaica.* Jamaica Workshop May 28, 2015; Suzanne Shaw and Mark Dennis
16. Petroleum Corporation of Jamaica (PCJ) (2015). *Developing Jamaica's Renewable Energy Potential*. Available from http://www.pcj.com/developing-jamaicas-renewable-energy-potential/
17. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013.* United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
18. Chad, B. (2017). *IRP to Include Hydropower as Source of Renewable Energy.* JIS News, 23 April 2018. Available from https://jis.gov.jm/irp-to-include-hydropower-as-source-of-renewable-energy/
19. Reynolds-Baker, A. (2014). *Government Signs Agreement for Hydro-Power Project.* Jamaica Information Service, 28 May 2014. Available from http://jis.gov.jm/government-signs-agreement-hydro-power-project/

Puerto Rico

2.1.8

International Centre on Small Hydro Power (ICSHP)

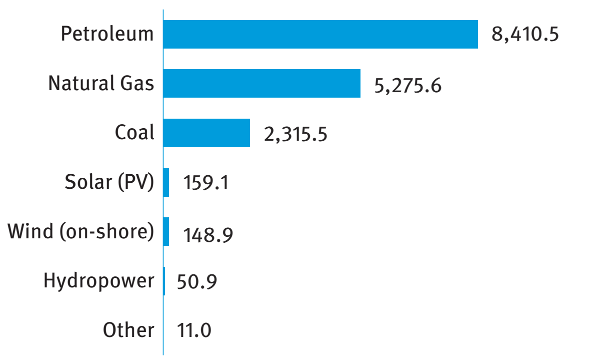
Key facts

Population	3,663,000[1]
Area	8,870 km² [2]
Climate	The climate of Puerto Rico is tropical rainforest and temperatures throughout the year are warm to hot, between 22 °C and 25 °C. The temperature in the southern coast is the warmest and a few degrees higher than that in the north. In the central interior mountains, the temperatures are cooler than in the rest of the island.[3]
Topography	Puerto Rico can be split into the three physiographic zones. The mountainous interior area is formed by the Cordillera Central, the central mountain chain that transects the island from east to west. The highest point is Cerro de Punta at 1,338 metres above sea level. The second zone is the coastal lowlands that extend 10-19 km inward in the north and south. Finally, the karst region, consisting of formations of rugged volcanic rock, extends into the north of the island.[3]
Rain pattern	Annual precipitation in the north is 1,550 mm, in the south 910 mm, in coastal regions 1,010-3,810 mm and in the mountains 5,080 mm. There is rainfall throughout the year, but it doubles from May to October, whereas January to April are considered to be the driest months.[3]
Hydrology	Puerto Rico has 224 rivers, with the main rivers draining the north and south areas. Due to the country's topography there are not long rivers or large lakes. [3] The longest river that flows to the northern coast is the Grande de Arecibo. Other rivers include La Plata, Cibuco, Loiza, Bayamon and the Grande de Anasco.[3] About 67 per cent of the superficial drain is from the central mountain ranges to the northern coast.[4]

Electricity sector overview

In 2016, the total installed capacity of Puerto Rico was estimated at 6,161.4 MW, with 5,800 MW from fossil fuels and 361.4 MW from renewable energy sources.[5,6] The total electrical generation of the country for 2017 was estimated at 16,371.72 GWh, with over 51 per cent from petroleum, 32 per cent from natural gas, 14 per cent from coal, 1 per cent from solar power (photovoltaics), almost 1 per cent from on-shore wind, and less than 1 per cent from hydropower and other technologies (Figure 1).[7] The large decrease in generation since the *World Small Hydropower Development Report 2016* is largely due to the hurricanes in the summer of 2017, in particular Hurricane Maria.

Figure 1.
Annual electricity generation by source in Puerto Rico (GWh)



Source: Indicadores.PR[7]

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

Table 1.
Average electricity tariff in Puerto Rico (US$ cents/kWh)

Type of consumer	*Average electricity tariffs (US$ cents/ kWh)*
Residential	20.47
Commercial	22.39
Industrial	18.64

Source: EIA[8]

Around 2 per cent of Puerto Rico's electricity comes from renewable energy, with wind and solar being the main sources.[8] There are two main wind farms on the island, one of which is the Santa Isabel 95 MW facility. It is also the largest wind farm in the Caribbean. [8] And, as of June 2017, the island had utility-scale solar (photovoltaic) of 127 MW installed capacity, as well as 88 MW distributed capacity.[8]

There are 21 hydropower generating units in Puerto Rico, some of which were built in 1915.[8] These 21 units have an aggregate capacity of approximately 100 MW. In 2017, these hydropower plants generated 50.9 GWh.[7] The recent severe weather conditions have reduced generation and even caused damage to dams.[13] However, before Hurricane Maria, many of the units did have mechanical problems which also resulted in reduced generation.[14]

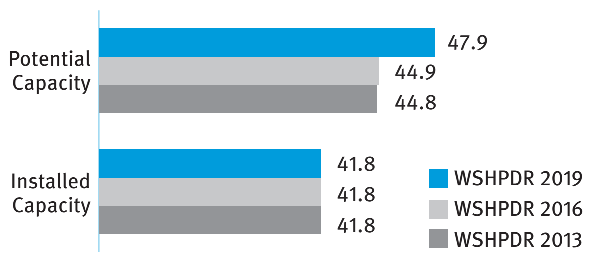
The electricity infrastructure in Puerto Rico, in particular generation, transmission and distribution systems, require modernization and significant funding in order to deal with reliability problems.[9] Furthermore, the generation system in Puerto Rico is 28 years older than the average electric power utility in the United States.[10] However the distribution network was destroyed in the summer of 2017 when Hurricane Maria struck, causing power outages that have lasted months.[11] The electrification rate, which was previously at 100 per cent, has not yet been fully restored, and stands at 85 per cent.[12]

Following the hurricane, the main concern of the island was restoring power, which was complicated by the situation of the power company, PREPA, and their debt of US$ 9 million.[11] In spring 2018 the island suffered major blackouts, but in August PREPA managed to restore electricity to almost all of the island.[28]

Small hydropower sector overview

This report for Puerto Rico considers small hydropower (SHP) as plants with a capacity of up to 10 MW. There are eight SHP plants in Puerto Rico, with an aggregated capacity of 41.8 MW distributed among 15 units with capacities below 10 MW (Figure 2).[14] However, two units in Patillas (0.8 MW units and 0.6 MW units) have not been in service for some time (Table 2).[14] Before Hurricane Maria, the Puerto Rico Aqueduct and Sewer Authority had plans to redevelop a 3 MW plant at the Carraizo Dam. The Carraizo plant was destroyed in 1989 by Hurricane Hugo and the lack of funding meant the hydropower plant could not be repaired.[15] The potential of this hydropower plant has not been included in the previous reports, which brings potential capacity up to 47.9 MW.

Figure 2.
Small hydropower capacities 2013/2016/2019 in Puerto Rico (MW)



Source: *WSHPDR 2013,*[27] *WSHPDR 2016,*[14] Ramirez et. al.[15]

Note: The comparison is between data from *WSHPDR 2013, WSHPDR 2016* and *WSHPDR 2019.*

Table 2.
Operational small hydropower plants in Puerto Rico

Plant Name	*Available capacity (MW)*	*Units*
Toro Negro 1	8.64	3 units x 1.44 MW 1 unit x 4.32 MW
Toro Negro 2	1.92	1 unit
Garzas 1	7.20	2 units x 3.6 MW
Garzas 2	5.04	1 unit
Yauco 2	9.00	2 units x 4.5 MW
Caonillas 2	3.60	1 unit
Rio Blanco	5.00	2 units x 2.5 MW
Total	**40.40**	**13 units**

Source: *WSHPDR 2016* [14]

The United States Geological Survey (USGS) data has been analysed to obtain the average discharge of the main rivers in Puerto Rico (44 in total).[16] Since all of the potential natural sites for large reservoirs have already been used, the main potential growth area for small hydropower is the micro-hydropower (units not exceeding 100 kW in capacity). The potential for micro-hydropower generation was determined using water flow and net head.[16] A net head range from 3 metres to 120 metres was considered due to variations from river to river or from location to location in the same river. Table 3 shows micro-hydropower generation capacity estimates.[14]

Table 3.
Estimated micro-hydropower capacity in Puerto Rico

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

Source: Puerto Rico State Energy Office[16]

Total micro-hydropower potential is approximately 3.1 MW, a small amount since it is 3 per cent of the total installed hydropower capacity. This was the first attempt to estimate micro-hydropower potential in Puerto Rico.[16] Not all potential sites were included in the estimate since many potential sites are not monitored.

Renewable energy policy

Since 2010, local and foreign renewable energies businesses could choose between two incentive schemes, the Economic Incentives for the Development of Puerto Rico (EIA) of 2008 and the Green Energy Fund (GEF) created by Act 83 of 2010.[17] The EIA provides some tax credits and incentives.

Tax incentives include a 4 per cent fixed income rate for 15 years and a 90 per cent exemption from property taxes for 15 years. Tax credits can be up to 50 per cent to cover the expenses related to qualified research and development or to cover the cost of machinery and equipment for the generation and efficient use of energy for companies that produce their own power. Companies producing energy for domestic consumption can benefit from the Green Energy Fund programme.

The Green Energy Fund, worth US$ 290 million and spanning over a ten-year period, supports three tiers of renewable energy projects.[18] Respectively, tier I, II and III targets correspond to residential and small businesses below 100 kW, mid-scale businesses between 100 kW to 1 MW, and large-scale businesses over 1 MW. According to PREPA estimates, distributed generation went from 37 MW to 70 MW in 2015, mainly due to solar PV systems.[14]

Act 83 of 2010 introduced Renewable Energy Certificates (RECs). These are assets equivalent to 1 MWh generated from a green energy source. Starting in 2013, for the 2015 year, RECs could be bought, sold or transferred between entities. This enabled Puerto Rico to participate in the United States renewable energy market, as well as this RECs are marketable abroad.[19]

The Renewable Portfolio Standard, created by Act 82 of 2010, set ambitious renewable energy production targets of 12 per cent by 2015, 15 per cent by 2020 and 20 per cent by 2035.[20] However PREPA failed to meet those targets with a total renewable energy generation barely reaching 1.5 per cent in 2015.[14]

PREPA has been applying very high rates to its customers and years of underinvestment left transmission and distribution networks poorly maintained. Yet, its inefficient collections and frequent turnover in management incurred PREPA to go deeply into debt.[10]

Act 57 of 2014, known as the Transformation and Energy Relief Act, created the Puerto Rico Energy Commission (PREC), an independent regulatory body overseeing PREPA's activities.[21] The commission is responsible for approving rate increases, and urged PREPA to prepare an integrated resource plan which would optimize transparency and energy efficiency for electricity coming from fossil fuels, and enable more renewable energy use at distribution level.

After Hurricane Maria struck Puerto Rico in September 2017 and the island's struggles to re-establish power over the territory, on January 4, 2018, PREC released proposals emphasizing the role of renewables by establishing microgrid installations.[22] The proposal defines that microgrids must qualify as either renewable (at least 75 per cent of power from clean energy), combined heat-and-power or hybrid, and "shall consist, at a minimum, of generation assets, loads and distribution infrastructure. Microgrids shall include sufficient generation, storage assets and advanced distribution technologies to serve load under normal operating and usage conditions."[23] These are, by definition, owned by entities other than PREPA, but small cooperatives can interconnect with PREPA's grid by incurring a monthly fee of between US$ 25-250.[24,25] The proposal has been submitted for public comment and once the regulation is completed the Commission will file an integrated resource plan in July 2018.[26]

Barriers to small hydropower development

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

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

- A lack of finance – between PREPA and its bankruptcy, finance of any type of power plant will be difficult. As well as this, investment might be difficult due to years of PREPA mismanagement.
- Limited SHP potential – compared with other renewable energy resources, in particular, solar, wind and tidal power.
- Severe weather that could lead to damage of hydropower equipment
- Lack of reservoir management – it is possible that if existing reservoirs were properly maintained, namely being dredged periodically, and if new generators that were put in place and if better water management were implemented, the potential for SHP could increase threefold;
- Limited water resources – water resources are used mainly for human consumption.
- Some obstacles associated with micro-hydropower include little experience with this option in Puerto Rico, and the division of regulatory oversight among local and federal (USA) agencies that does not present a clear permitting process for hydropower alternatives.[11,14]

References

1. United Nations, Department of Economic and Social Affairs, Population Division. *World Population Prospects: The 2017 Revision, Key Findings and Advance Tables. Working Paper No. ESA/P/WP/248.* New York: United Nations, 2017.
2. The World Bank Group. *Data Bank, World Development Indicators.* 2017. http://databank.worldbank.org/data/reports.aspx?source=2&country=PRK (accessed January 16, 2018).
3. Rivera, Magaly. *Welcome to Puerto Rico.* 2018. http://welcome.topuertorico.org/geogra.shtml (accessed February 26, 2018).
4. Figueroa-Alamo, C.; Aquino, Z.; Guzmán-Ríos, S. and Sánchez, A. V. *Water Resources Data for Puerto Rico and US Virgin Islands Water Year 2004*: *Water-Data Report PR-04-1. Guaynabo*. United States Department of the Interior and United States Geological Survey, 2006.
5. IRENA. "International Renewable Energy Agency." *Capacity and Generation.* 2017. http://resourceirena.irena.org/gateway/dashboard/?topic=4&subTopic=16 (accessed February 11, 2018).
6. United Nations. *The 2015 Energy Statistics Yearbook.* The

Department of Economic and Social Affairs, United Nations Statistical Division, New York: United Nations, 2017.

7. Indicadores.PR. "indicadores.pr." *Generación consumo costo ingresos y clientes del sistema el eléctrico de Puerto Rico.* February 22, 2018. https://indicadores.pr/en/dataset/generacion-consumo-costo-ingresos-y-clientes-del-sistema-electrico-de-puerto-rico/resource/fdad4f42-a4be-48bb-9478-a8fb75c000c6 (accessed February 22, 2018).
8. U.S. Energy Information Admministration. *EIA: Puerto Rico.* 2017. https://www.eia.gov/state/print.php?sid=RQ (accessed February 26, 2018).
9. Fisher, Jeremy, and Ariel Horrowitz. *Puerto Rico Energy Commission: review of ratesof the Puerto Rico Electric Power Authority.* Governemnt of Puerto Rico, 2016.
10. Bases, Daniel. "Reuters: Business News." *Puerto Rico to sell off crippled power utility PREPA.* January 23, 2018. https://www.reuters.com/article/us-puertorico-power-prepa/puerto-rico-to-sell-off-crippled-power-utility-prepa-idUSKBN1FB31M (accessed February 28, 2018).
11. Church, Steven. "Bloomberg." *Puerto Rico Faces Blackouts Again, This Time Due to Bankruptcy.* February 17, 2018. https://www.bloomberg.com/news/articles/2018-02-16/puerto-rico-faces-blackouts-again-this-time-due-to-bankruptcy (accessed February 28, 2018).
12. Government of Puerto Rico. *statuspr.* 2018. http://status.pr/Home?lng=en (accessed February 26, 2018).
13. Kaske, Michelle. "BloombergMarkets." *Puerto Rico may get $2 billion for power grid, Governor says.* February 8, 2018. https://www.bloomberg.com/news/articles/2018-02-07/puerto-rico-may-get-2-billion-for-power-grid-governor-says (accessed February 28, 2018).
14. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
15. Ramirez, L., A. Quinones, *R. Boyce, I. Botero, and R. Frias. "Hydroworld.com." Planning to Rehabilitate the 3 MW Lago Loiza Plant after 24 Year Closure.* 1 April 2017. http://www.hydroworld.com/articles/print/volume-25/iss*ue-2/features/planning-to-rehabilitate-the-3-mw-lago-loiza-plant-after-24-*year-closure.html (accessed February 28, 2018).
16. Irizarry Rivera, A.A, J.A. Colucci-Rios, and E O'Neill- Carrillo. *Achievable Renewable Energy Targets For Puerto Rico's Renewable Energy Portfolio Standard.* Puerto Rico: Puerto Rico State Energy Office, 2009.
17. Calderwood, H., and D. Sarkisian. "DSIRE." *Puerto Rico - Economic Development Incentives for Renewables.* 20 October 2016. http://programs.dsireusa.org/system/program/detail/3185 (accessed February 28, 2018).
18. Calderwood, H. „DSIRE." *Puerto Rico - Green Energy Fund.* May 6, 2015. http://programs.dsireusa.org/system/program/detail/4944 (accessed February 28, 2018).
19. Oficina Estatal de Politica Publica Energetica. „Oficina Estatal de Politica Publica Energetica." *Green Energy Fund, Renewable Platform.* 2010. http://www.prgef.com/renewableplatform (accessed February 28, 2018).
20. LexJuris de Puerto Rico. „LexJuris de Puerto Rico." *Ley Núm. 82 del año 2010 (Energy Diversification Law).* July 19, 2010. http://www.lexjuris.com/lexlex/Leyes2010/lexl2010082.htm (accessed February 28, 2018).
21. Ferris, David. E&E NEWS. October 13, 2017. https://www.eenews.net/stories/1060063551 (accessed February 28, 2018).
22. Puerto Rico Energy Commisison. *Regulation on Microgrid Development*. Puerto Rico: CEPR(Comision Energia de Puerto Rico), 2018.
23. Puerto Rico Energy Commisison. *Regulation on Microgrid Development - Section 3.01.* Puerto Rico: CEPR(Comision Energia de Puerto Rico), 2018.
24. Microgrids are acting as a "single controllable entity with respect to PREPA's grid", Puerto Rico Energy Commisison. *Regulation on Microgrid Development - Section 1.08.* Puerto Rico: CEPR(Comision Energia de Puerto Rico), 2018.
25. Puerto Rico Energy Commisison. *Regulation on Microgrid Development- Section 4.05.* Puerto Rico: CEPR(Comision Energia de Puerto Rico), 2018.
26. Merchant, Emma Foehringer. „gtm." *Puerto Rico Energy Commission Lays Out Rules for a Future Microgrid Landscape.* January 8, 2018. https://www.greentechmedia.com/articles/read/puerto-rico-energy-commission-island-microgrid#gs.Rb697E0 (accessed February 28, 2018).
27. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org

2.1.9

Saint Lucia

Peter Norville, Water and Sewerage Company Inc.

Key facts

Population	174,417[1]
Area	616 km[2]
Climate	Saint Lucia has a tropical maritime climate characterized by warm air temperature averaging close to 28 °C, rarely rising above 32 °C or falling below 21 °C. Temperatures are lowest in the months of December to March, and highest around June to September.[2]
Topography	Saint Lucia has a very rugged landscape, characterized by mountains along a centrally located north-south oriented mountain range, deep valleys and rivers. The highest point is Mount Gimie at 950 metres above sea level.[2]
Rain pattern	Saint Lucia has two climatic seasons based on rainfall. The wet season extends from June to November and the dry season runs from December to May. The geographic influence of rainfall is pronounced, with total annual rainfall varying from about 1,265 mm in the flat coastal regions to about 3,420 mm in the elevated interior region.[2]
Hydrology	There are 37 watersheds in Saint Lucia, of which the Roseau watershed is the largest. A number of small rivers flow outward from the central highlands to the coast, and the principal rivers are the Roseau, Cul de Sac, Fond D'Or, Troumassee, and Vieux Fort rivers.[3]

Electricity sector overview

St. Lucia Electricity Services Limited (LUCELEC), which is privately owned, is the sole electricity utility company in Saint Lucia. LUCELEC's available capacity in 2017 was 88.4 MW, with a firm capacity of 68.0 MW and a peak demand of 61.7 MW. Saint Lucia is almost totally reliant on imported fossil fuels for electricity generation, however in November 2017, LUCELEC commenced a project to establish a 3 MW solar farm. In April 2018, electricity from this solar farm began feeding into the LUCELEC electricity grid.[6] Figure 1 shows the installed capacity by these sources in 2018.

Figure 1.
Installed electrical capacity by source in Saint Lucia (MW)

Source: Department of Finance,[1] Joseph C.[6]

As the solar farm has just been established, generation data is unavailable, with all electricity by LUCELEC in 2017 being from diesel-powered generators. The total electricity generated by LUCELEC in 2017 was 400.3 GWh, an increase of 2.3 per cent over 2016.[1] The electrification rate of Saint Lucia is approximately 98 per cent. [5]

LUCELEC reported an overall tariff for 2017 at 0.28 US$/kWh.[4] In addition to the Basic Energy Rates, which are adjusted annually, a fuel cost adjustment rate (commonly referred to as a Fuel Surcharge) is applied to the number of units used and is added to every bill. The fuel cost adjustment rate changes each month depending on fuel prices and the amount of fuel used in the generation of electricity.[7] The additional fuel charge in 2017 was 0.01 US$/kWh.[4]

Table 1.
Description of electrical consumption in Saint Lucia

Type of customer	*Number of accounts*	*Average consumption (kWh)*	*Total sales units generated (GWh)*	*Tariff (US$/kWh)*	*Fuel charge (US$/kWh)*
Domestic	59,620	2,142	127.73	0.28	0.01
Commercial (including hotels)	7,052	28,754	202.77	0.28	0.01
Industrial	93	196,301	18.26	0.28	0.01
Street lighting	19	N/A	10.90	0.28	0.01

Source: LUCELEC[4]

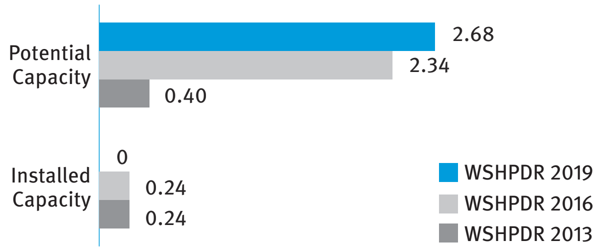
The number of LUCELEC customer accounts at the end of 2017 totalled at 66,784, compared to 65,974 for 2016, with the total number of customer accounts by sector average annual consumption per customer as recorded by LUCELEC during 2017 listed in Table 1.[4] The total sales units generated by LUCELEC in 2017 was 359.65 GWh, an increase of 3.3

percent over 2016. Details of the sales for each customer type in 2017 is also summarised in Table 1.[4]

Small hydropower sector overview

There is no official definition of SHP in Saint Lucia. The definition of 10 MW or less will be used for this report. There are no hydropower plants operating in Saint Lucia. A small plant, of 240 kW, which was installed at a small eco-touristic attraction at Latille Falls several years ago is no longer operational, due to damage incurred during a storm. The operator of the Latille Falls attraction has indicated interest in bringing the hydropower plant back into operation but requires assistance in doing so.

Figure 2.
Small hydropower capacities 2013/2016/2019 in Saint Lucia (MW)



Source: Caribbean Renewable Energy Development Program,[8] *WSHPDR 2013*,[10] *WSHPDR 2016*[11]

Note: The comparison is between data from *WSHPDR 2013, WSHPDR 2016* and *WSHPDR 2019.*

Figure 2 shows the potential capacity and installed capacity of Saint Lucia. The potential capacity has increased from 2.340 MW to 2.676 MW. This is because a more recent feasibility study was completed in 2015 for the establishment of a hydropower plant at the John Compton Dam. This feasibility study identified the best option to be a 300 kW diagonal type turbine as the main turbine with a 36 kW pump as a turbine for processing the riparian flow, giving a potential capacity of 336 kW. The study also concluded that, depending on the amount of water abstracted as drinking water, the hydropower plant could generate between 811 MWh and 950 MWh per year.[8]

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

Renewable energy policy

The Government of Saint Lucia has adopted a National Energy Policy to create an enabling environment, both regulatory and institutional, for the introduction of indigenous renewable energy to the national energy mix, thus achieving greater energy security and independence.[9]

In 2014, the Government of Saint Lucia announced a variety of energy targets. It set a renewable energy penetration target of 35 per cent and an energy efficiency target of a 20 per cent reduction in consumption in the public sector, both to be achieved by 2020.[9]

In 2017, the Government and LUCELEC completed the National Energy Transition Strategy, which is a forward-looking strategy for the energy sector. An Integrated Resource Plan (IRP) from this strategy finds that a portfolio of centrally owned diesel, solar, wind, and energy storage methods is the best option economically, whilst also providing continued reliability.[9]

The National Utilities Regulatory Commission Act No. 3 of 2016 established the National Utility Regulatory Commission (NURC) to regulate utility supply services, including electricity supply. The Electricity Supply (Amendment) Act No. 2 of 2016 provides for the regulation of Electricity Supply Service by the NURC. However, regulations required to support the main legislation and to bring full effect to the regulation of the electricity sector by the NURC have not been passed.

Barriers to small hydropower development

In general, hydropower does not feature in Saint Lucia's development plans. However, there appears to be an opportunity to harness hydropower, in particular small hydropower, from the John Compton Dam. The main barriers to small hydropower development include, but are not limited to:

- The generally low baseflows of the main rivers, which are unable to support hydropower plants
- Other renewable energy sources, particularly solar power, are given a higher priority in the Government's policies, and in public and private-sector projects.[11]

References

1. Saint Lucia, Department of Finance (2018). Economic and Social Review 2017. Castries. Available from https://www.finance.gov.lc/resources/download/2076
2. Saint Lucia, Ministry of Education, Innovation, Gender Relations and Sustainable Development (2017). Saint Lucia's Third National Communication on Climate Change. Available from http://www.climatechange.govt.lc/resource/saint-lucias-third-national-communication-on-climate-change-2017/
3. Morgan, Frank Dale and Burke J. Misley. Watershed-river analysis of St. Lucia, West Indies. Massachusetts Institute of Technology, 2012.
4. St. Lucia Electricity Services Limited (LUCELEC) (2018). 2017 Annual Report. Castries. Available from http://www.lucelec.com/sites/default/files/annual-reports/LUCELEC-2017-Annual-Report.pdf
5. National Renewable Energy Laboratory (2015). Energy Snapshot-Saint Lucia. Energy Transition Initiative. Available from https://

www.nrel.gov/docs/fy15osti/62688.pdf
6. Joseph, C (2018). 3 MW Solar Farm Now Feeding LUCELEC Grid. St. Lucia Electricity Services Limited, April 13. Available from http://www.lucelec.com/content/3-mw-solar-farm-now-feeding-lucelec-grid
7. St. Lucia Electricity Services Limited (LUCELEC) (2018). Rates and Service Standards. Castries. Available from http://www.lucelec.com/content/rates-service-standards
8. Homscheid, Sven (2015). John Compton Dam Hydropower Plant Feasibility Study. Caribbean Renewable Energy Development Programme and Deutsche Gellschaft fur Internationale Zusammenarbeit (GIZ).
9. Torbert, Roy, Kaitlyn Bunker, Stephen Doig, Justin Locke, Stephen Mushegan, Siana Teelucksingh. Saint Lucia National Energy Transition Strategy and Integrated Resource Plan. Rocky Mountain Institute, 2017. Available from http://www.govt.lc/media.govt.lc/www/pressroom/news/attachments/saint-lucia-nets-executive-summary-final.pdf
10. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
11. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.

2.1.10 Saint Vincent and the Grenadines

International Center on Small Hydro Power (ICSHP)

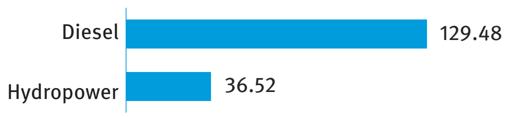
Key facts

Population	109,643[1]
Area	389 km²
Climate	The climate of Saint Vincent and the Grenadines is tropical, characterised by increased humidity and uniform temperatures across the years. The average annual temperatures are estimated at 26 °C. September is the hottest month, with temperatures reaching an average of 29 °C. February is considered the coldest and windiest month. Winds in February reach on average 23 km/h and the average temperature is 25 °C.[3]
Topography	Saint Vincent and Grenadines is a mountainous and volcanic island, located at the North of Trinidad and Tobago. It borders the Caribbean Sea at the West and the Atlantic Ocean at the East. Its highest point is Soufriere, an active volcano with an altitude of 1,234 metres. Roughly 36 per cent of the country is covered by forests and woodlands, with tropical forests across most of Saint Vincent area. Mount Tobai, on Union Island, is the highest point in the Grenadines, with an altitude of 308 metres. The topography of the Grenadines is characterised by beaches and shallow bays. Steep slopes and rugged landscapes comprise the remaining territory of Saint Vincent.[4]
Rain pattern	The average precipitation of Saint Vincent and the Grenadines has seen a decline of around 8.2 mm per month.[5] Rainfall is an important source of freshwater for the Grenadines and this decline is likely to affect water resources in the region. The annual precipitation is estimated to be between 2,000 mm and 6,000 mm, with the total mean runoff of 2,000 mm to 5,000 mm per year.[6]
Hydrology	There are no navigable rivers in Saint Vincent and the Grenadines, most of them being short and straight. Colonaire is the longest river on the island. Other important rivers are the Buccament, Cumberland and Warrowarrow. River defences were planned to be constructed on Colonaire, Buccament, Cumberland and Warrowarrow by the Government of Saint Vincent and the Grenadines as part of the Disaster Vulnerability Reduction Project (DVRP).[7]

Electricity sector overview

According to the United Nations data, electricity generation in 2015 was 166 GWh. Diesel accounted for 78 per cent of electricity generated, while 22 per cent is from hydropower sources (Figure 1).[8] The electricity in Saint Vincent and the Grenadines' islands of Bequia, Canouan, Mayreau and Union Island is generated, transmitted and distributed by St Vincent Electricity Services Ltd (VINLEC), which owns the monopoly in the region. Privately owned systems supply electricity to the other Grenadines islands of Mustique and Palm Island. These systems generate electricity through diesel and manage and operate the plants as part of their resorts. Each island has a power grid.[6] Peak demand in Saint Vincent and the Grenadines is estimated at 21 MW.[8]

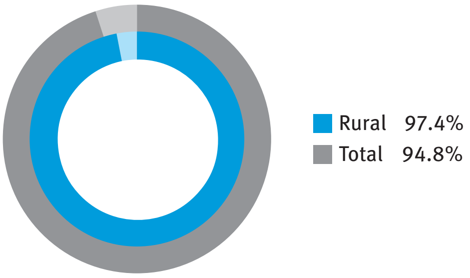
Figure 1.
Annual electricity generation by source in Saint Vincent and the Grenadines (GWh)



Source: UN Data,[8] NREL[9]

Total access to electricity is estimated at 97.4 per cent in Saint Vincent and the Grenadines (SVG), urban access to electricity standing at a rate of 100 per cent. Rural access to electricity is 94.8 per cent. Figure 2 below is a representation of the current access to electricity on the island.

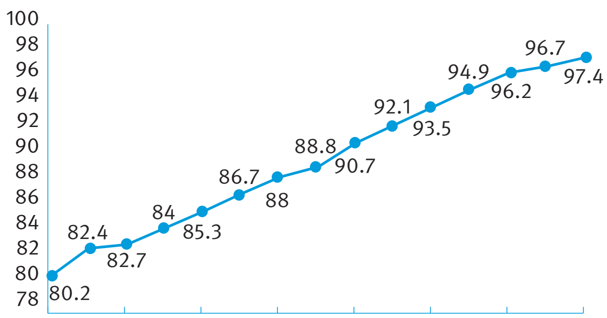
Figure 2.
Electrification rate in Saint Vincent and the Grenadines (%)



Source: UN Data[8]

Access to electricity improved on an annual basis both in the rural and urban regions. Figure 3 shows the evolution of electricity access in SVG between 2000 and 2014.

Figure 3.
Evolution of access to electricity in Saint Vincent and the Grenadines (%)



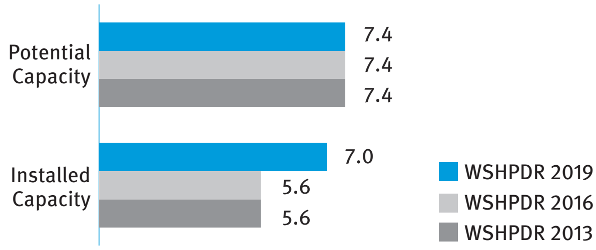
Source: UN Data[8]

Saint Vincent Electricity Services Limited (VINLEC) uses networks spanning over 350 miles to provide electricity to customers. It became a fully owned state enterprise in 1985. The organization was incorporated in 1961. Only in 1971 the Government of Saint Vincent and the Grenadines purchased 49 per cent of the shares of VINLEC.[10] The average tariffs for electricity were 0.22-0.29 US$/kWh for residential users, 0.29-0.31 US$/kWh for commercial users, 0.25-0.26 US$/kWh for industrial users and 0.32 US$/kWh for public lighting.[9,11] According to VINLEC, a Value Added Tax (VAT) of 15 per cent is applicable to domestic customers who consume more than 200 kWh. This tax is also paid by all commercial and industrial customers.[12]

Small hydropower sector overview

The definition used by the country for small hydropower (SHP) is up to 10 MW. The World Energy Council estimates the installed capacity of SHP in Saint Vincent at 7 MW. Potential capacity was estimated in the *World Small Hydropower Development Report (WSHPDR) 2016* at 7.4 MW and the figure is based on the planned projects in development phase. However, the actual SHP potential in the country might be much larger. Figure 4 below shows the increase in the installed capacity of SHP from the *WSHPDR 2013* to *WSHPDR 2019*.[11,13]

Figure 4.
Small hydropower capacities 2013-2016-2019 in Saint Vincent and the Grenadines (MW)



Source: *WSHPDR 2013*,[16] *WSHPDR 2016*,[11] World Energy Council[13]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

A study for the rehabilitation of the 1.1 MW Richmond Hydropower Plant and the expansion of South Rivers Hydropower Plant was conducted in 2009. Due to the favourable findings, VINLEC was prompted to undertake modernization and refurbishment projects at both plants. The first such initiative commenced in 2013. VINLEC also plans to develop a second power plant of 1.1 MW downstream South Rivers, on the Colonarie. The enterprise collaborates closely with the Government of Saint Vincent in promoting renewable energy in the region.[14]

The 7 MW installed capacity comes from three hydropower plants in Saint Vincent. Modernization work is still in progress at present, both the Government and VINLEC aiming to enhance the efficiency of the plants.

Renewable energy policy

The cost of energy in Saint Vincent and the Grenadines is very high. However there is significant potential for the adoption and implementation of renewable energy (RE) projects. In order to address sustainability issues, the Government of Saint Vincent established the National Energy Plan (NEP) in 2009. In 2010, an additional document, the National Energy Action Plan (NEAP), provided more accurate details with regards to the initiatives both the public and the private sector will undertake to promote the dissemination of renewable energy projects in the region.[9]

While the National Energy Action Plan (NEAP) specified a diverse variety of measures for implementation and even designed short and long-term targets, it has not been very effective so far, as numerous projects have only been commenced recently. NEAP mentioned that it aimed to reach 30 per cent electricity output produced through renewable energy by 2015 and 60 per cent reliance on RE for electricity by 2020.[15] The country's potential is high, however financial and construction policies to motivate and accommodate investors are still needed.

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

- Ribishi Point was identified as a suitable site for development of wind power after a 2005 study conducted by VINLEC. The state-owned company plans to develop local expertise in the installation, operation and maintenance of renewable energy systems. There is also a plan to construct a wind park at Ribishi Point.
- The installation of a 177 kW solar PV system was recently completed at the Cane Hall Stores Building. Testing of the system will be soon performed.
- A 360 kW solar PV plant installation project is underway at the Lowmans Bay Power Station.
- Generating electricity through the recovery of heat from waste is another measure that the Government of Saint Vincent is considering.[14]

Barriers to small hydropower development

There are numerous barriers to small hydropower development:

- The lack of a specific plan on SHP development is one of the major issues
- While VINLEC is making attempts to encourage customers' investment in small hydropower and renewable energy, the market is still heavily reliant on fossil fuels for electricity production.
- VINLEC's monopoly in the region may prevent smaller private companies from effectively developing and implementing renewable energy projects at profitable rates.
- Small hydropower is no longer a priority for the Government of Saint Vincent and the Grenadines. Most investment is focused on the developing solar and geothermal programmes.[14]

References

1. World Bank (2016). *Population, total.* Available from http://data.worldbank.org/indicator/SP.POP.TOTL .
2. Central Intelligence Agency (CIA) Data (2016). *Saint Vincent and the Grenadines.* Available from http://www.cia.gov
3. Time and Date official website, Custom Weather Data (2017). *Saint Vincent and the Grenadines.* Available from https://www.timeanddate.com
4. Nations Encyclopedia (n.d). *St. Vincent and Grenadines topography.* Available from http://www.nationsencyclopedia.com/Americas/St-Vincent-and-the-Grenadines-TOPOGRAPHY.html.
5. Mc Sweeney, New and Lizcano (2008), *UNDP Climate Change Country Profile: St. Vincent and the Grenadines.* Available from http://ncsp.undp.org 6. The International Journal on Hydropower and Dams (2015). *2015 World Atlas & Industry Guide.*
6. Available from www.hydropower-dams.com.
7. 1Government of Saint Vincent and the Grenadines. (2010). *Disaster Vulnerability Reduction Project (DVRP) Environmental Assessment Report.* Central Planning Division. Ministry of Finance and Economic Planning. Available from www.gov.vc
8. United Nations Data (2015). *Energy Statistics: Saint Vincent and the Grenadines.* Energy Statistics Database. Available from http://www.data.un.org
9. United States of America, National Renewable Energy Laboratory (NREL) (2015). *St Vincent and Grenadines.* Available from http://www.nrel.gov/docs/fy15osti/64127.pdf.
10. Saint Vincent Electricity Services Limited (VINLEC) (2017). *About Vinlec.* Available from http://www.vinlec.com
11. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016.* United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
12. Saint Vincent Electricity Services Limited (VINLEC) (2017). *About your electricity bill.* Available from http://www.vinlec.com
13. World Energy Council. *Latin America and the Caribbean Hydropower Data.* (checked on January 2018). Available from http://www.worldenergy.org
14. Saint Vincent Electricity Services Limited (VINLEC) (2017). *Renewable Energy.* Available from http://www.vinlec.com
15. Reegle (2012). *Saint Vincent.* Available from http://www.reegle.info/policy-and-regulatory-overviews/VC.
16. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from: www.smallhydroworld.org. Accessed 15 April 2018

2.2 Central America

José Fábrega, Universidad Tecnológica de Panamá and National Research System of Panamá (SNI)

Introduction to the region

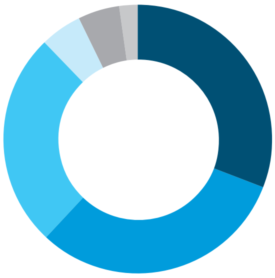
Central America comprises the region bordered by the Pacific Ocean to the west and the Caribbean Sea and the Gulf of Mexico to the east. The region includes eight countries – Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua and Panama. While the overall geographic shape of the region is narrow, its topography and climate vary widely. Northern Mexico is arid, while the southern regions of the country are humid to very humid. For the rest of the region, the climate is defined by altitude and proximity to the coast. For example, in Guatemala, the climate is temperate in areas above 1,000-2,000 metres, while the lower regions are tropical, with temperatures that can reach 40 °C.[3]

Mexico has 158 river basins with a total mean runoff estimated at 379,000 hm^3/year. In Honduras, the most important river is the Ulúa, which flows 400 km to the Caribbean Sea. In Belize, of the 18 major rivers and many perennial streams, the Belize River is the largest (290 km). In Nicaragua, the Rio Grande and its tributaries are the most extensive river system. El Salvador has ten hydrographic regions that drain into the Pacific Ocean and the Lempa River. Costa Rica is divided into 34 major basins, 17 basins for each side, with sizes between 207 km^2 and 5,084 km^2. There are 52 watersheds and approximately 500 rivers in Panama. Most of these rivers (70 per cent) run to the Pacific side (longer streams), with the other 30 per cent running to the Caribbean side. The most important river in Panama is the Chagres River, which forms the basin where the Panama Canal is located.

An overview of the countries of Central America is presented in Table 1. Mexico has the highest installed capacity of SHP in the region. The distribution of SHP up to 10 MW across the countries of the region is shown in Figure 1.

The Central American Electric Interconnection System (SIEPAC) was completed in 2014, creating a regional energy market among El Salvador, Guatemala, Honduras, Costa Rica, Nicaragua and Panama. The SIECAP allows the countries to exchange energy up to 300 MW. There are also plans to connect Mexico to the SIECAP. Besides the SIEPAC, a transmission line of 103 km links Mexico and Guatemala since April 2010. It has a capacity of 200 MW towards Guatemala and 70 MW in the opposite direction. Mexico is also connected to Belize by a transmission line with a capacity of 65 MW. To the north, Mexico has 11 interconnections with Texas and California in the USA, with capacities ranging from 36 MW to 800 MW. There was great interest in a 2012 plan that would link Panama and Colombia through a 614 km interconnection. However, this project has yet to be realized.[7,8,9]

Figure 1.
Share of regional installed capacity of small hydropower up to 10 MW by country in Central America (%)



Source: *WSHPDR 2019*[3]

Note: Does not include Guatemala and Mexico as data on capacity up to 10 MW is not available.

Table 1.
Overview of countries in Central America

Country	*Total population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Belize	0.4	54	92	158	397	55	261
Costa Rica	5.1	21	99	3,530	11,210	2,328	8,677
El Salvador	6.5	29	96	1,846	5,700	575	1,339
Guatemala	16.2	49	91	4,072	11,490	1,438	5,765
Honduras	9.3	44	88	2,571	9,345	676	3,088
Mexico	124.7	20	99	55,889	263,393	12,125	29,138
Nicaragua	6.2	42	82	1,482	4,527	143	468
Panama	4.0	33	94	3,401	10,936	1,777	7,253
Total	**172.4**	-	-	**72,949**	**316,998**	**19,117**	**55,989**

Source: *WSHPDR 2019,*[3] WB,[4] WB,[5] MEM[6]

The reduction of electricity tariffs and the inclusion of more renewable energy (RE) sources might become a major political challenge in the future. Except for Mexico (0.06-0.08 US$/kWh for domestic and industrial use), electricity tariffs are high in most countries of the region. The opposition to new hydropower projects by the local population (native groups in many cases) is another political challenge that the region is facing.[3]

Small hydropower definition

The definition of SHP varies throughout the region (Table 2). Costa Rica and Belize do not have an official definition of SHP, but Costa Rica considers installed capacity less than 20 MW to be plants with limited capacity. The rest of the countries have some specific classification, with the highest being a capacity of 30 MW in Mexico and Honduras.

Regional small hydropower overview and renewable energy policy

Despite the large number of watercourses in the region and the important role that large hydropower plants play in the energy sector of the region (18 per cent of annual generation), SHP has continued to remain a small fraction of overall hydropower generation. However, in terms of installed capacity, SHP projects have grown by 47 per cent compared to the *World Small Hydropower Development Report* (*WSHPDR*) *2016*, having reached a total capacity of 524 MW, mainly due to new capacities commissioned in Mexico (Figure 3). Also, there is still a large untapped potential of 742 MW (based on local definitions of SHP), but more feasibility studies need to be conducted in order for many countries to fully utilize their SHP potential (Figure 2).

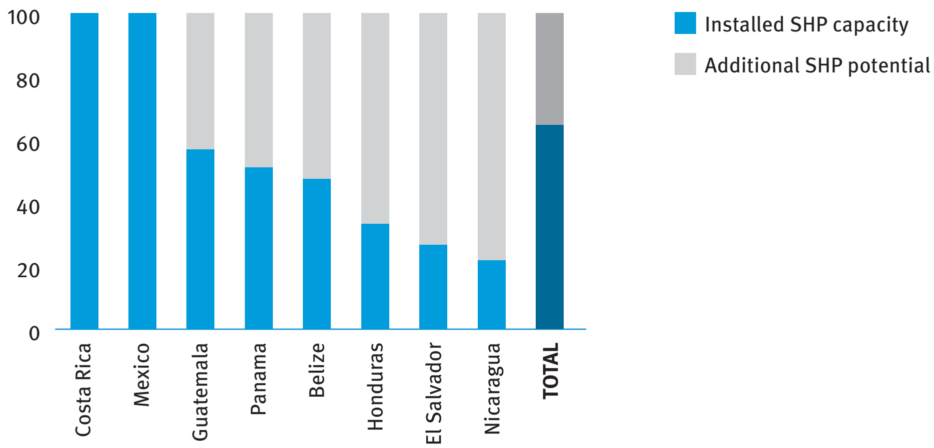
Table 2.
Small hydropower capacities in Central America (local and ICSHP definition) (MW)

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed (<10 MW)*	*Potential (<10 MW)*
Belize	-	-	-	10.3	21.7
Costa Rica	-	-	-	125.5	125.5*
El Salvador	up to 20	42.0	158.0	22.6	119.8
Guatemala	up to 5	114.3	201.0	114.3**	201.0**
Honduras	up to 30	301.8	N/A	128.0	385.0
Mexico	up to 30	699.3	N/A	N/A	N/A
Nicaragua	up to 10	18.6	85.7	18.6	85.7
Panama	up to 20	213.5	417.0	104.8	263.3
Total		-	-	**524**	**1,202**

Source: *WSHPDR 2019*[3]

Note: * The estimate is based on the installed capacity as no data on potential capacity is available. ** Data as per the local definition of SHP.

Figure 2.
Utilized small hydropower potential by country in Central America (local SHP definition) (%)



Source: *WSHPDR 2019*[3]

Note: This Figure illustrates data for local SHP definitions or the definition up to 10 MW in case of the absence of an official local one. For Honduras, the data is presented for the SHP definition up to 10 MW due to the absence of data on potential capacity according to the local definition. For Costa Rica and Mexico, the additional potential is not known.

An overview of SHP in the countries of Central America is outlined below. The information used in this section is extracted from the country profiles, which provide detailed information on SHP capacity and potential, among other energy-related information.

In **Belize**, the installed capacity of SHP plants below 10 MW has not changed since the *WSHPDR 2016* and remains at 10.3 MW. The additional potential is estimated to be at least 11.4 MW, indicating that 48 nearly 50 per cent of the country's potential has been developed. The national development plan of Belize, called Horizon 2030, includes the promotion of green energy and energy efficiency as one of its strategic priorities. This includes the creation of an institutional framework for producing a viable energy policy. The country's National Sustainable Energy Strategy 2012-2033 aims to institutionalize a countrywide infrastructure to collect data, in order to identify feasible sites for the development of solar, wind and hydropower energy.

In terms of RE development, **Costa Rica** has heavily invested in the sector and has become a world leader in the generation of electricity through RE sources. The installed capacity of SHP up to 10 MW in Costa Rica is reported to be 125.5 MW, while the available potential remains unknown. However, SHP does not seem to be a priority among RE sources. In the 2016-2035 Generation Expansion Plan, there are no planned SHP projects from public services distribution companies.[9] In addition, over the last years, moratoriums on hydropower development (including SHP) have been signed by some municipal councils concerned about the environmental impacts. Finally, the central Government also established a moratorium on watersheds with a high potential for HP development.[3] In general, the energy plans in Costa Rica aim to diversify RE sources, especially with respect to non-conventional sources (wind, solar and biomass), however, with no specific plans for hydropower or SHP development.

In **El Salvador**, the installed capacity of SHP up to 10 MW is 22.6 MW. The slight increase, compared to the *WSHPDR 2016*, is due to the modernization and refurbishment of certain plants. The potential capacity is at least 119.8 MW and could be developed by the year 2026. In terms of RE policies, one of the strategic guidelines of the National Energy Policy 2010-2024 (NEP) is the diversification of the energy mix and the promotion of RE sources. Therefore, to ease the implementation of RE generation projects, several adjustments were made to the legal and regulatory frameworks of the electricity and environmental sectors, and to taxation regulations.

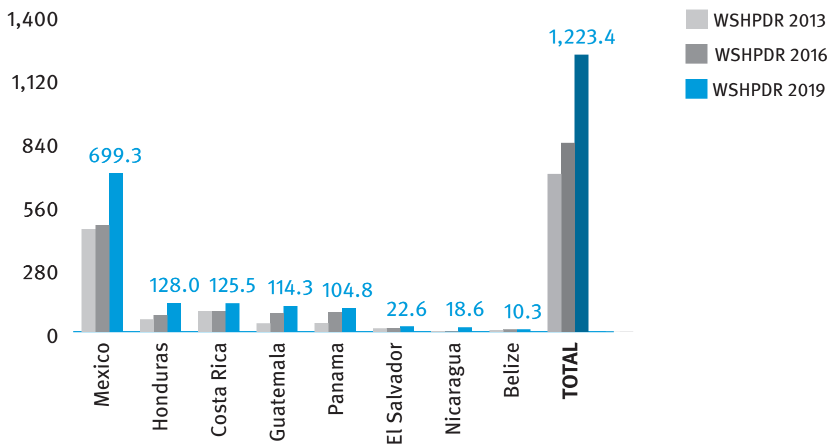
In **Guatemala**, the installed capacity for SHP plants up to 5 MW was 114.3 MW, while the potential is estimated to be at least 201.0 MW, indicating that approximately 57 per cent of the known potential has been developed. The 2013-2027 Energy Policy includes plans for the promotion of RE sources in electricity generation, with a long-term goal of generating 80 per cent of electricity from RE. There is also the National Energy Plan 2017-2032, which establishes an additional installed capacity target of 6,102 MW by 2032, with 58 per cent coming from hydropower. This Plan also promotes the "Law of Incentives for Renewable Energy Development", energy efficiency and the reduction of greenhouse gas emissions by 29.2 per cent by 2032.

The installed SHP capacity of **Honduras** (up to 10 MW) increased to 128 MW, with the potential estimated at 385 MW. The Government of Honduras intended to reverse the structure of the country's electricity sector to a ratio of 60 per cent RE and 40 per cent fossil fuel by 2022, but the target has already been achieved. Also, the Honduras Scaling-Up Renewable Energy Programme in Low-Income Countries (SREP) is financing a series of activities aimed mainly at improving rural electrification and developing the RE sector in the country.

In the case of **Mexico**, the installed SHP capacity (up to 30 MW) reached 699.3 MW. This increase is due to a large number of generation permits issued before the 2013 Energy Reform, to developers willing to benefit from the previous regulatory framework. The new Government plan from the 2018 Presidential election focuses on reducing the use of natural gas by increasing the generation of existing hydropower plans and building new ones. Also, this plan aims to reduce domestic electricity tariffs. The potential of SHP in Mexico remains unknown.

In **Nicaragua**, there are 14 operational SHP plants up to 10 MW with a combined capacity of 18.61 MW, and a further 20 potential sites with a combined capacity of 67.06 MW were identified. Even though there is no RE policy in place in Nicaragua, the National Energy Policy (2004) established a framework for the promotion of RE energy. Also, the Plan for Electricity Generation Expansion for the 2016-2030 period includes the addition of 1,223 MW of new capacity, of which 783 MW will come from RE sources. From these RE sources, hydropower will see the greatest capacity addition in the coming decade. Also, there is a favourable legal and attractive incentive structure for SHP projects up to 5 MW.[3]

Figure 3.
Change in installed capacity of small hydropower from *WSHPDR 2013* to *2019* by country in Central America (MW)



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

Note: *WSHPDR* stands for *World Small Hydropower Development Report.* For Guatemala, data is for SHP up to 5 MW; for Mexico, up to 30 MW; for other countries, up to 10 MW.

It is reported that for SHP up to 10 MW, in **Panama**, there are 20 plants with a combined installed capacity of 104.8 MW and 33 plants with concessions granted or pending with a combined capacity of 158.45 MW. High prices and energy consumption levels led to the promulgation of Law 44 of April 2011, which aims to promote wind power and diversity in RE sources. Also, the Paris Climate Change Agreement has become a driver for the promotion of the use of RE sources. Panama has pledged to increase the RE share in its electricity generation mix by 30 per cent by the end of 2050, employing the year 2014 as a baseline.[3]

No **feed-in tariffs (FITs)** have been introduced in the region, however, a range of other incentives for the development of RE technologies are granted by the Governments in the region.

Barriers to small hydropower development

There are three major challenges to SHP development found throughout the region. First, a lack of solid financial frameworks for SHP investment is common to all countries. It translates into limited funds available for commercial banks, high interest rates, the need for long-term financial assistance, loan requirements that are difficult to comply with for SHP projects and dependence of remote communities solely on Government funds.

Second, there is a need for better policies, legislation and regulatory processes to promote SHP projects. In the region, it is easy to observe a promotion of RE sources within the energy mix of each country. However, there are preferences for the development of other types of RE projects, rather than SHP.

Third, in the last years, there have been social and environmental concerns regarding hydropower projects, which also affect SHP. This is particularly the case for **Costa Rica**, where some municipal Governments and the central Government, due to concerns about the environmental impacts, introduced moratoriums on hydropower development. In **Guatemala**, as a result of environmental and social opposition to the development of hydropower, the Ministry of Energy and Mines has developed a consulting methodology for local populations based on the International Labour Organization's "C169, Indigenous and Tribal Peoples Convention".[3]

In **El Salvador**, the construction of power plants can also face public opposition. Moreover, some project development areas are affected by insecurity and violence. There is also a lack of reliable river flow data series and detailed hydropower potential inventories. **Mexico** also lacks reliable hydrological data and hydropower projects are associated with social and community concerns. Moreover, the process of obtaining permits and licences is complex and costly, with multiple authorities involved in the decision-making process and imposing various restrictions. There is also a lack of coverage and maintenance of the roads and of the electric grid in areas with high hydropower potential, requiring major investments. In **Honduras**, there is a need to invest into transmission networks and to develop the ancillary services markets.

In **Belize**, SHP development is complicated by the unregulated market, the lack of standards and of a Standard Offer Contract (SOC) for Renewable Energy Generation, as well as by a limited skilled labour force in the SHP sector. In **Nicaragua**, power purchase agreements are of too short a duration as to motivate SHP project development. Finally, in **Panama**, financial limitations are the key barrier, with the level of investment in SHP projects remaining low.

References

1. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
2. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
3. LIU, D., LIU, H., WANG, X., and Kremere, E., eds. (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
4. World Bank (2017). Rural population (% of total population). Available from https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS.
5. World Bank (2016). *Access the electricity (% of population).* Available from https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS.
6. Ministry of Energy and Mines of Guatemala (MEM) (2017). *Generación Eléctrica de Centroamérica y Panamá 2017*. Available from https://www.mem.gob.gt/energia/estadisticas-energia/estadisticas-energeticas/.
7. ICE (2017). *Plan de Expansión de la Generación Eléctrica*. San José: ICE, 2017.
8. The Potential of Regional Power Sector Integration (2010). Economic Consulting Associates Limited, UK.
9. Organisation for Economic Co-operation and Development (OECD) (2014). *Latin American Competition Forum - Session II - Electricity Markets in Latin America: Regional Integration and Competition Issue, Contribution from Costa Rica (DAF/COMP/LACF(2014)26).* Available from www.oecd.org.

2.2.1 Belize

Henrik Personn, Caribbean Community Climate Change Centre

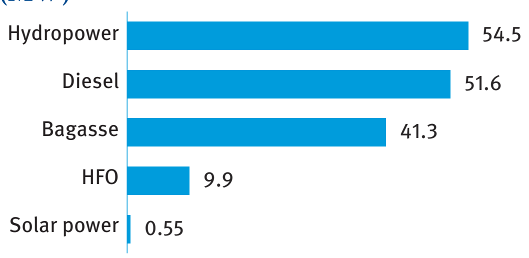
Key facts

Population	366,954[1]
Area	22,966 km²
Climate	The climate in Belize is tropical, hot and humid. Temperatures range from 10 °C to 35 °C with an annual mean of 26 °C. November to January are the coolest months with an average temperature of 24 °C. May to September are the warmest with an average temperature of 27 °C. In Cayo in the west, temperatures can be several degrees colder than along the coast with night time temperatures sometimes falling below 8 °C in November.[2]
Topography	The north of Belize is a flat, swampy coastal plain, while in the south lies the low mountain range of the Maya Mountains. The highest point is Doyles Delight at 1,160 metres.[2]
Rain pattern	The rainy season lasts from May to November, and the dry season is from February to April. 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	Eighteen major rivers and many perennial streams flow through Belize. The largest river is the Belize River (290 km) which flows along the northern edge of the Maya Mountains across the centre of the country to the Caribbean and drains more than one-quarter of the country's surface area. Other important rivers include the Sibun River, which drains the north-eastern edge of the Maya Mountains, and the New River, which flows through the northern regions before emptying into Chetumal Bay.[3]

Electricity sector overview

In 2017, the total installed capacity of licensed power producers was 157.85 MW, which implies an addition of 16 MW compared to the *World Small Hydropower Development Report (WSHPDR) 2016*.[4,16] The reason for this is the addition of the 16 MW bagasse power plant of Santander Sugar Energy close to Belmopan. Hydropower and diesel dominated the country's energy mix, accounting for approximately 35 and 33 per cent of total installed capacity, respectively. Bagasse accounted for 26 per cent of total installed capacity, heavy fuel oil (HFO) for 6 per cent and solar power for 0.3 per cent (Figure 1).[4] Thus, renewable energy sources represented 61 per cent of the country's energy mix, while fossil fuels provide the remaining 39 per cent. The list of power plants operating in Belize is shown in Table 1.

Figure 1.
Installed electricity capacity by source in Belize (MW)



Source: BEL[4]

Table 1.
List of power plants in Belize (MW)

Name	*Total installed capacity (MW)*	*Description*
Belize Electric Limited (BEL)	29.10	A diesel-fired gas turbine rated at 22.5 MW, but its actual output is typically 20.0 MW. In addition, the utility deploys 6 x 1.1 MW mobile high-speed diesel units at different nodes in their network, including a 2.2 MW diesel generator in Caye Caulker.
Belize Aquaculture Limited (BAL)	22.50	BAL owns a power plant that operates 3 x 7.5 MW Wartsila medium-speed diesel units. The facility was initially a self-generator for its aquaculture operations but is currently providing 15 MW on a standby arrangement to BEL.
Belize Co-Generation Energy Limited (BELCO-GEN)	27.5	Generates electricity burning bagasse and heavy fuel oil using two 90 ton/hr boilers expanding into 1 x 12.5 MW (back-pressure) and 15 MW (condensing/extraction) turbines nominally exporting 13.5 MW into the grid. Bagasse accounts for 25.3 MW of installed capacity and HFO for 2.2 MW.

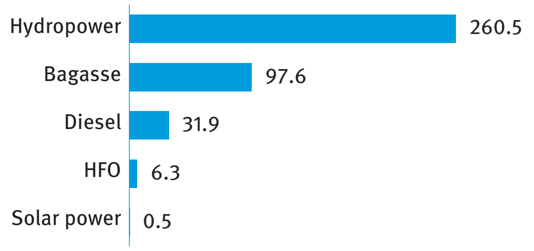
Name	*Total installed capacity (MW)*	*Description*
Santander Sugar Energy Limited (SSE)	16	SSE has a 16 MW cogeneration power plant that provides steam to their sugar refinery and electricity to the national grid. According to the power purchase agreement with BEL, with the first 8 MW turbine SSE exports to the grid 25 GWh annually. Full operation of the 16 MW capacity is expected in 2018.
Farmer's Light Plant	7.70	Operates five diesel generators with rated capacities of 2 x 2.2 MW and 3 x 1.1 MW that run on crude oil. This power plant is licensed by the Public Utilities Commission, but is uncoupled from the BEL grid and operates only for the Spanish Lookout Mennonite community.
Mollejon Hydroelectric Plant	25.20	Located on the Macal River. It has 3 x 8.4 MW Francis turbines with a typical output of 8 MW during the dry season and 21 MW during the wet season.
Vaca Hydroelectric Plant	19.00	Vaca has a live storage capacity of 1.25 million m^3, which allows the hydropower facility to operate for 10 hours at full capacity. The plant has 2 x 9 MW and 1 x 1 MW vertical Francis turbines.
Chalillo Hydroelectric Dam and Plant	7.30	Located on the Macal River; has 2 x 3.65 MW turbines.
Hydro Maya Limited (HML)	3.00	Run-of-river hydropower plant with units of 1 x 2.4 MW and 1 x 0.6 MW.
Photovoltaic Plant at University of Belize	0.48	Grid-feeding photovoltaic plant located in Belmopan at the University of Belize Campus.
Photovoltaic Plant at Belize Water Services	0.07	Grid-feeding photovoltaic plant located in Caye Caulker installed on the reverse osmosis plant to reduce the amount of electricity drawn from the island grid.
Total	**157.85**	

Source: Personn[5]

In 2016, power plants in Belize generated 397 GWh of electricity, with hydropower accounting for 66 per cent of the total (Figure 2). A further 243 GWh was imported from the Federal Electricity Commission (CFE) of Mexico. Thus, total electricity supply in Belize in 2016 was 640 GWh.[4] It is estimated that in 2017 Belize Electricity Limited (BEL) sold 665 GWh of electricity to 87,000 customers and had a system peak load of 93 MW.[5]

The main electricity generation licence holder is BEL, which is an incorporated company and majority owned by the Government. BEL is the sole electricity utility company in Belize, owning the local grid, electric meters and the single sales licence from the PUC. BEL has the licence to generate, transmit and supply electricity throughout Belize. As of 2017, other generation licensees supplying power and associated energy to the BEL national grid system included Santander Sugar Energy (SSE) using bagasse, Hydro Maya Limited (hydropower facility), BELCOGEN Limited (using bagasse) and BAPCOL (using HFO). Other potential entities for inclusion under the regulatory umbrella of the electricity sector are BECOL (hydropower facility), Famer's Light Plant Limited (generation and distribution provider in Spanish Lookout Mennonite Community) and other small self-generators with capacities of above 75 kW. These entities are expected to be licensed and subsequently regulated by the Public Utilities Commission (PUC).

Figure 2.
Annual electricity generation by source in Belize (GWh)



Source: BEL4

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 (AR) of tariffs and full tariff review (FTR) every four years for the BEL;
- Licensees compliance audits;
- Reliability and efficiency review for licensees.

In establishing the PUC, the Government also gave it duties and mandates to enact legislation to regulate the entities involved in the electricity sector. The main legislative instruments used are:

- The PUC Act;
- The Electricity Act;
- Subsidiary legislation on tariffs, fees and charges;
- Licences issued to entities involved in generation, transmission and distribution of power and energy;
- Other subsidiary legislation such as orders, statutory Instruments and by-laws used by the Commission to give effect to new tariffs and other legal conditions to be followed by licensees.

The Ministry of Finance, Public Service, Energy and Public Utilities (MFPSEPU), formerly known as the Ministry of Energy, Science and Technology and Public Utilities (MESTPU), is the body responsible for arranging and steering the Belizean Government's financial and monetary policies and strategies. This involves creating and allotting financial resources for the purpose of making social services available to everyone, in order to foster further development of Belize. The ministry comprises an energy unit, which has the mandate to introduce and promote energy efficiency, renewable energy and clean energy production.

In December 1998, BEL completed an interconnection between its transmission system and that of the Federal Electricity Commission (CFE) of Mexico. The interconnection has 115 kV with 50 MW capacity and completed the existing 115 kV transmission grid system. In 2005, BEL completed a 69 kV transmission facility that allowed connecting all the southern load centres (Dangriga, Independence/Placencia and Punta Gorda) as well as completed the existing national transmission grid system connecting all load centres in the country, except for Caye Caulker.[5]

The national transmission grid services currently approximately 98 per cent of the country's electricity demand. Caye Caulker remains the lone isolated load centre and is supplied by a diesel power plant. In other remote rural areas and cayes (small, sandy, low-lying islands) without connection to the grid, households, communities and other entities use a mix of diesel generators, small-scale photovoltaic systems or wind turbines to supply electricity for their own needs. In 2016, 92 per cent of the population had access to electricity, with 97 per cent in urban areas and 88 per cent in rural areas.[1]

Table 2.
Electricity tariff rates by consumption

Tariff type	*Tariff (US$/kWh)*	*Additional monthly charges*
Social rate		
0 - 60 kWh	0.11	Minimum charge is US$ 1.75
Residential rate		
0 - 50 kWh	0.15	Minimum charge is US$ 2.50
51 - 200 kWh	0.18	
≥ 201 kWh	0.20	
Commercial 1 (less than 2,500 kWh)		
0 - 50 kWh	0.15	Minimum charge is US$ 2.50
51 - 200 kWh	0.18	
≥201 kWh	0.20	
Commercial 2 (above 2,500 kWh)		
0 - 10,000 kWh	0.19	Service charge is US$ 62.50
10,001 – 20,000 kWh	0.19	
≥ 20,001 kWh	0.18	
Industrial		
Demand of 18 kVA	0.14	Service charge is US$ 62.50
Demand of 11.25 kVA	0.12	
Street lights	0.21	

Source: BEL[8]

The national transmission grid consists of:

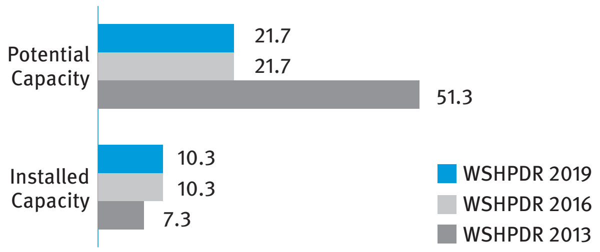
- A 115 kV transmission line (approximately 160 km) running from the XUL-HA substation located in Mexico to the West Lake Substation in Belize located 13 km from Belize City on the George Price Highway with taps at the Buena Vista substation and the Maskall substation with a capacity of 50 MW;
- A 115 kV transmission line (approximately 13 km) running from the West Lake substation to the Belize City substation;
- A 115 kV transmission line (approximately 160 km) running from the Mollejon Hydropower Plant to the West Lake substation with taps to Vaca Hydropower Plant, San Ignacio substation, Belmopan substation and the La Democracia substation;
- A 69 kV transmission line (approximately 209 km) running from the La Democracia substation to the Punta Gorda distribution substation, with taps to the Dangriga substation, the BAPCOL generating plant and the Independence substation.[7]

Table 2 provides the tariff rates approved by the PUC for the period from 1 January 2016 to 30 June 2020.

Small hydropower sector overview

Belize has no official small hydropower definition. However, this report assumes a definition of up to 10 MW. The installed capacity of small hydropower plants below 10 MW is 10.3 MW, and the additional potential is estimated to be at least 11.4 MW, indicating that 47.5 per cent of the country's potential has been developed.[5,10] Compared to the results of the *World Small Hydropower Development Report (WSHPDR) 2016*, both the installed and potential capacities of small hydropower in Belize have remained unchanged (Figure 3).

Figure 3.
Small hydropower capacities 2013/2016/2019 in Belize (MW)



Source: *WSHPDR 2013*,[6] POYRY,[9] *WSHPDR 2016*,[12] MESTPU[13]

Note: The comparison is between the data from *WSHPDR 2013*, *WSHPDR2016* and *WSHPDR2019*.

At the moment, Belize has four licensed hydropower facilities which are feeding the BEL grid. The biggest hydropower system comprises three plants with a combined capacity of 51.5 MW and is fed by the Chalillo Dam. The live storage capacity of the Chalillo Dam is 120 million m^3 with the capacity to supply water to Chalillo, Mollejon and Vaca for 55 days at full capacity. The generation capacity at the Chalillo Dam is only 7.3 MW as the primary purpose of the dam is to store water in the rainy season and release it during the dry season.[5]

The Mollejon hydropower plant is located a few kilometres downstream. It utilizes the run-of-river technology and has an on-site live storage capacity of 1 million m^3, which enables the operation of the plant for 12 hours at full capacity. The installed capacity of the plant is 25.2 MW with three vertical Francis turbines of 8.4 MW each. The Vaca hydropower plant is the last in the compound and is located 5 kilometres downstream from the Mollejon plant. The Vaca plant has an on-site live storage capacity of 1.25 million m^3, which enables the operation of the plant for 10 hours at full capacity. Its installed capacity is 19 MW with two vertical Francis turbines of 9 MW and one of 1 MW.[5]

Hydro Maya is the fourth hydropower plant in Belize that feeds into the national grid. It is a run-of-river plant with a maximum capacity of 3 MW with one turbine of 2.4 MW and one of 0.6 MW.[5]

Therefore, the installed small hydropower capacity up to 10 MW comes from two operational small hydropower plants, Chalillo Hydroelectric and the Hydro Maya Limited. Together they account for approximately 19 per cent of total hydropower capacity and approximately 7 per cent of total installed capacity in the country.

While the country's hydropower potential is relatively low there are still potential sites for further hydropower development, without the need to inundate large areas of the rainforest for storage reservoirs, as stated in a 2006 study of the hydropower potential of Belize.[9] Sites with a potential of less than 20 MW listed in the study include:

- The Macal River Project with a potential capacity of 8.4 MW, which has an easy access to lines of the national power network;
- Tributaries to the Macal River with the conditions to install a small hydropower plant with a capacity of 2 MW;
- A site along the Privassion River with a potential capacity of 1 MW;
- Potential low-head power plants along the Mopan River, which could be installed in a cascade system with a maximum capacity of 15-20 MW.

There are a number of other potential sites across the country, such as the Chiquibul development, the Bladen and Swasey branch development of the Monkey River or the South Stann Creek project. However, no data exists to provide accurate assessments of their potential capacity.[13] There is no defined financial mechanism for small hydropower projects in Belize, but certain incentives do exist. For example, funds or credits for clean energy investments can be applied for with Beltraide or the Development Finance Corporation (DFC). However, neither is specifically focused on small hydropower.[10,11] Additionally, Request for Proposals (RfP) for Power Purchase Agreements (PPAs) and similar incentives, such as the call by the PUC in November 2013 to submit proposals to generate electricity to be sold to the Government, have been issued. It is expected that the PUC will issue a new call for proposals in 2018.

Renewable energy policy

The principles of sustainable development are embodied in the national development plan of Belize called Horizon 2030. One of the strategic priorities of Horizon 2030 is the promotion of green energy and energy efficiency and conservation, including the creation of an institutional framework for producing a viable energy policy. In February 2012, the Government endorsed the National Energy Policy and Planning Framework, which developed the Strategic Plan 2012-2017, including "The Belize National Sustainable Energy Strategy 2012-2030". It aims to institutionalize a countrywide infrastructure to collect data and assess the potential for converting solar, wind and hydropower to electricity, and to identify feasible sites for development. One of its goals (goal 5) is to increase hydropower capacity up to 70 MW by 2033. It suggests a revision of the technical assessments of hydropower resources to identify new sources, determine the potential and develop expansion plans.[13]

The Government has conducted several studies, which were not public at the time of publishing of this report. These studies analyze the electricity sector and the needed development in the next few years. Some of the conducted studies are the Sustainable Energy Action Plan for Belize by Castalia (2014, CASTALIA, Sustainable Energy Action Plan, Belize, Belmopan) and the Energy Sector of Belize by the Inter-American Development Bank in 2014 (IDB, 2014, The Energy Sector, Belmopan, Belize). Based on the Government policies and the findings of the studies, the PUC is advancing a renewable energy law, which was open for public commenting until the end of 2017. Nevertheless, the progress in developing the law is very slow and at this point it is not clear whether the law will be adopted or will be newly drafted. As of mid-2018, Belize had no legal framework for renewable energy grid feeding.

Barriers to small hydropower development

The main barriers to small hydropower development in Belize include:

- An unregulated market, which stems from political considerations, favouring BEL and non-flexible generation schemes;
- A lack of Standard Offer Contract (SOC) for Renewable Energy Generation;
- No automatic investment security for investors;
- A Lack of standards in the small hydropower sector, resulting in technical instability;
- A limited skilled workforce for small hydropower.

Targeted policy, regulatory, and financial interventions as well as targeted programmes with a focus on small hydropower could help overcome the barriers that prevent further development of small hydropower in Belize.

References

1. World Bank Data (2016). Belize. Available from https://data.worldbank.org/country/belize
2. World Fact Index (n.d.). Belize, (n.d.) Available from http://wor-

ldfacts.us/Belize-geography.htm
3. Belize Rivers (n.d.). Rivers of Belize with their tributaries. Available from https://web.archive.org/web/20060205093549/http://www.belizerivers.org/rivers/index.htm
4. Belize Electricity Limited (BEL) (2016). Annual Report 2016. Available from http://www.bel.com.bz/annual_reports/Annual%20Report%202016.pdf
5. Personn, H. (2017). Investigation into the substitution of fossil fuel based power generation in Belize – a technical, economic and ecological feasibility study, Beuth University, Berlin.
6. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013.* United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
7. Belize Electricity Limited (BEL) (2014). Electric System Presentation. Available from http://www.puc.bz/index.php/publications/electricity-sector/others/3-pre-bid-presentation/file
8. Belize Electricity Limited (BEL) (2016). Rate Schedule. Available from http://www.bel.com.bz/Rate_Schedule.aspx
9. PÖYRY Energy Ltd (2006). Belize Hydroelectric Development - Technical Report, MESTPU, Belmopan
10. Beltraide (n.d.). Official Website. Available from http://www.belizeinvest.org.bz
11. Development Finance Corporation (DFC) (n.d.). Official Website. Available from http://www.dfcbelize.org/renewable-energy-loans/
12. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
13. Ministry of Energy, Science & Technology and Public Utilities (MESTPU) (2012). Strategic Plan 2012-2017. Available from http://www.publicservice.gov.bz/jdownloads/Strategic%20Plans/MESTPU_Strategic_Plan_-_2012-2017.pdf

2.2.2 Costa Rica

Marco Antonio Jimenez Chavez, Costa Rica Electricity Institute (ICE); Laura Lizano Ramon, Energy Sector Planning Secretariat, Ministry of Environment and Energy of the Republic of Costa Rica

Key facts

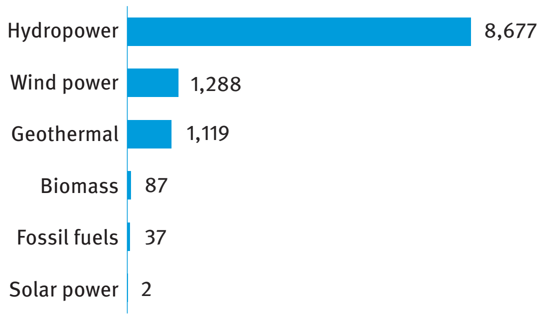
Population	5,058,007 [1]
Area	51,100 km^2 [1]
Climate	Costa Rica lies within the tropical zone, between the Tropics of Cancer and Capricorn. The average annual temperature is 25 °C. Furthermore, the country is divided in three general climate regions – the Tropical Caribbean Wet Region with monthly mean extreme temperatures between 22 °C and 31 °C, the Central Intermontane Region with monthly mean extreme temperatures between 13 °C and 27 °C, and the Tropical Pacific Region with monthly mean extreme temperatures between 23 °C and 33 °C.[2,3]
Topography	The topography is irregular, with valleys, mountain ranges, and plains. Three main mountain ranges divide the country in two slopes – Pacific and 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. Mount Chirripó is the highest mountain in Costa Rica, with an elevation of 3,819 metres.[4]
Rain pattern	Annual average accumulated rainfall is 3,297 mm. Different rain patterns occur in the Caribbean and Pacific slopes. The Caribbean slope is wetter, without a defined dry season. Heavy rainfall occurs in December. Lower rainfall occurs 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 a defined wet and dry season. The former extends between December and March. The latter extends between May and October. April and November are transition periods. The Northern Pacific is the driest zone with an annual average rainfall as low as 1,400 mm in the lowlands.[4]
Hydrology	The territory is divided in 34 main watersheds, 18 in the Caribbean slope and 16 in the Pacific slope. The largest is the Grande de Térraba watershed in 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. Caribbean and Southern Pacific river flows are as high as 180 lps, per km^2 of watershed area. Grande de Térraba river has the highest mean annual flow, with 340 m^3 per second. Northern Pacific river flows are lower than 30 lps, per km^2 of watershed area.[4]

Electricity sector overview

Electricity generation in 2017 reached 11,210 GWh, with 99.7 per cent coming from renewable energy sources, mainly hydropower (77.4 per cent). Seasonal variation of electricity consumption is minor, slightly higher in the dry season. Domestic electricity demand was 11,019 GWh. Surplus electricity was sold in the Regional Electric Market (MER). Figure 1 shows the country's electricity generation mix in 2017. The share from renewable energy sources attained its highest level in 30 years.[8]

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

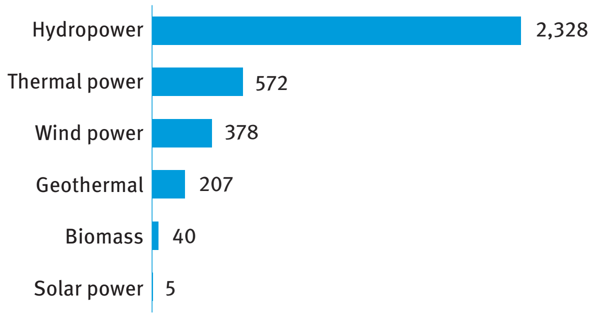
Figure 1.
Annual electricity generation by source in Costa Rica (GWh)



Source: ICE[8]

The installed capacity in 2017 was 3,530 MW – 66 per cent hydropower, 16 per cent fossil fuel thermal plants, 11 per cent wind power, 5.85 per cent geothermal, 1 per cent biomass and 0.15 per cent solar.[5] Figure 2 shows the installed electricity capacity by sources.

Figure 2.
Installed electricity capacity by source in Costa Rica (MW)



Source: ICE[5]

National electrification rate in 2016 was 99.3 per cent.[7] Electricity demand grew by 0.8 per cent in 2017.[5] GDP grew by 3.9 per cent in the same period.[8] WWF Green Energy Leaders 2014 Report recognized Costa Rica as the leader in Latin America.[9] The Energy Architecture Performance Index Report 2017 and the Global Competitiveness Index Report 2017-2018 ranked the electrical supply quality in third place among the region.[10,11]

The public company, the Costa Rica Electricity Institute (ICE), guarantees the electricity supply needed for the country's development, as mandated by Law 449.[12] ICE produces most of the electricity, and manages the transmission system and most of the distribution lines. Furthermore, the company is responsible for the planning and overall operation of the SEN.[7]

In 2017, ICE generated the biggest share, accounting for 66 per cent of the total energy generation. The share of public services distribution companies was 12 per cent. The private sector generation contributed with 22 per cent, primarily through hydroelectric energy. The size of power plants is regulated by Law 7,200 – 20 MW maximum power for Build, Own and Operate (BOO) plants, and 50 MW maximum power for Build, Operate and Transfer (BOT) contracts with national and foreign private investors. Privately generated energy is sold to ICE.[5,13]

Transmission lines extend widely, between the Nicaragua and Panama borders and the Caribbean and Pacific coasts, summing 1,633 km with 230 kV and 628 km with 138 kV. In 2014, the Electric Interconnection System of the Central America Countries (SIEPAC) was completed, and a regional energy market (MER) was created.[7]

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 plants.[14] The Central Valley is the main electricity consumption zone. Distribution lines are managed by eight public services companies, including ICE.[7] In 2017, SEN accomplished ten years of service without outages.[15]

The long-term planning of SEN is defined by ICE in Electric Generation Expansion Plans, which are updated and published frequently. For the 2016-2035 period, the estimated future electricity demand is estimated to increase annually between 2.3 per cent and 4.4 per cent. Capacity additions will be mostly renewables.

Electricity prices in Costa Rica are regulated, with no subsidies. Caps on the electricity tariffs are defined on a temporary basis.[16] The Public Services Regulatory Authority (ARESEP) defines methodologies for fixing the tariffs. Strong variations occur among public services distribution companies located in urban or rural zones. The lowest electricity price in May 2017 was 0.11 US$/kWh in urban zones for consumption rates below 200 kWh per month. The highest price was 0.24 US$/kWh in rural zones, for consumption rates above 200 kWh per month.[17]

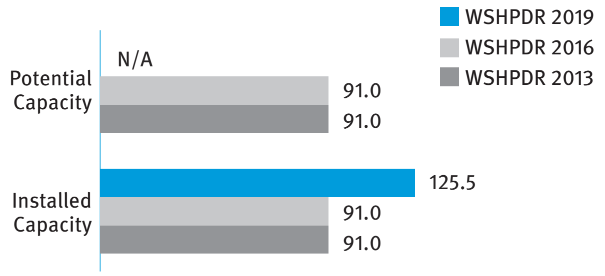
Small hydropower sector overview

The 2018 investigation for the current report found 36 small hydropower (SHP) plants (10 MW or less) in operation. The total installed capacity was 125.5 MW, including four inactive SHP plants or plants with unknown status. The majority of SHP plants are connected to the grid. Off-grid SHP plants are used for personal supply or in remote national parks, providing electricity support for the Ministry of Environment and Energy (MINAE) environmental protection tasks, for instance in Cocos Island and Mount Chirripó National Parks. Public service distribution companies and private owners hold most of the SHP capacity in operation, 60 per cent and 34 per cent, respectively, while ICE holds 5.3 per cent. The National Lighting Company (CNFL), which is the Central Valley public service distribution company and ICE´s subsidiary, owns most of the oldest SHP plants.[18] Some of them are from the early twentieth century, and thus in need for refurbishment according to ICE dam safety studies.[19] Figure 3 shows the installed and potential SHP capacity in Costa Rica. Costa Rica has a massive theoretical hydropower potential, estimated at over 4,000 to 7,000 MW, yet the potential for SHP remains unidentified.

Law 7200 defines that the private sector can produce autonomous energy with limited capacity power plants (LCP), defined as 20 MW or lower power plants, small-scale hydropower or from non-conventional sources.[13] The 2018 investigation for the current report found 49 LCP hydropower plants in operation. Total installed capacity was 352 MW, including five inactive and unknown status plants.[18]

No official local estimation of specific SHP potential exists for the country. ICE reports 7,317 MW as the total identified hydropower potential capacity, regardless of the plant size. In this report, the identified potential is assumed as the technical potential. Nearly 35 per cent of the undeveloped capacity was in indigenous territories and 20 per cent in national parks and reserve forests.[7]

Figure 3.
Small hydropower capacities 2013/2016/2019 in Costa Rica (MW)

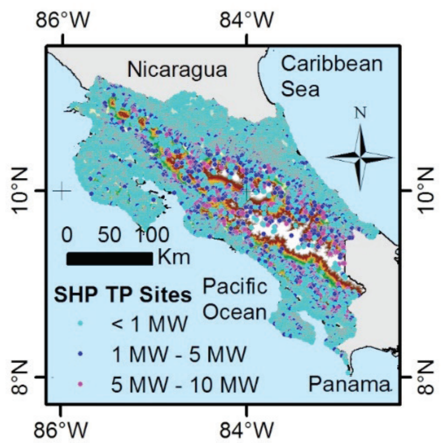


Source: *WSHPDR 2013*,[41] *WSHPDR 2016*,[42] ICE[7]

Note: The comparison is between data from *WSHPDR 2013, WSHPDR 2016* and *WSHPDR 2019*.

A different study shows larger potential based on a systematic high-resolution assessment of worldwide hydropower potential, by plant sizes.[20] Figure 4 shows SHP theoretical potential (TP) sites for a total of 10,042 MW.[20] Total hydropower TP sites, regardless of the plant size, sum up to 10,613 MW. The different colour points on the map represent potential hydropower sites. Light blue is used for SHP under one MW, dark blue for SHP between one MW and five MW, and pink for SHP above five MW and below or equal to 10 MW.

Figure 4.
Small hydropower theoretical potential sites in Costa Rica (MW)



Source: Hoes et al.[20]

Future studies must be conducted towards an estimation of the potential SHP capacity from various perspectives, e.g. technical, economic and environmental perspectives. The Hydropower Potential Assessment Tool (HPAT) by Mosier et al, or local GIS gridded information might be used for this purpose.[21]

Electrical development started by means of SHP plants in 1884, with the construction of 50 kW Aranjuez SHP plant, for San Jose streets lighting. Costa Rica's capital became one of the first cities in the world with electrical public lighting. At the start of the 20th century, several SHP plants were implemented across the country for electricity consumption. In 1928 the struggle for the nationalization of hydroelectric sources led to the creation of the National Electricity Service. In 1949, the Government created ICE. The main task allocated by Law 449 was to develop hydropower resources, in order to strengthen the economy and promote the greater well-being of the people of Costa Rica. Since then, ICE has led the country hydropower development, focused on large-scale plants.[22] In 1990, Law 7200 boosted SHP private development, regulating Build Own and Operate (BOO) contracts, with LCP plants.[13]

The licensing process for new private LCP plants is defined in Law 7200 Regulation. For the sake of a suitable balance between electricity generation and demand, ICE calls for LCP bids. Private investors interested in hydropower LCP developments submit eligibility applications. Licensing approval requires ICE declaration of eligibility, granted concession from the Ministry of Environment and Energy (MINAE) Water Department, granted concession form ARESEP and National Technical Environmental Secretariat (SETENA) declaration of Environmental Viability Licence.[23]

The licensing process for public services distribution companies is defined by Law 8345, which allows the use of the country's energy sources to meet the demand in their coverage areas. Granted concessions from the Ministry of Environment and Energy (MINAE) Water Department for projects with less than 60 MW and from the National Technical Environmental Secretariat (SETENA) with a declaration of Environmental Viability Licence are the main requisites.[24]

No planned SHP projects from public services distribution companies are reported in the 2016-2035 Generation Expansion Plan. Approved eligibility LCP projects from different renewable energy sources total 61 projects, for a total of 740 MW. However, Law 7200 limits total private LCP installed capacity to 15 per cent of SEN installed capacity. For example, in 2015 only 165 MW LCP could have been incorporated into SEN.[7]

In the last few years, some municipal councils, concerned by the environmental impacts of hydropower development, signed moratoriums on hydropower developments in their territories, including SHP.[25] The central Government also signed a hydropower moratorium on high potential watersheds.[26]

Hydropower funding came from public banks and trust funds. National and international private banks have also participated in the financing. Moreover, Costa Rica was one of the first countries using the Kyoto Protocol Clean Development Mechanism (CDM). Several SHP plants were developed using this financial scheme.[29] Recently, the country participates in a CDM project named Guacamaya Small Scale Hydropower.[30] Private projects sell the energy to ICE, according to ARESEP tariffs.[31] No feed-in tariffs, subsidies or other incentives are applied.

Renewable energy policy

Renewable energy policies can be traced back to 1949, with the creation of ICE. Law 449 entrusted ICE with the "rational development of the physical energy productive sources that the Nation possesses, especially the hydraulic resources".[12]

In 1990, Law 7200 authorized autonomous or parallel generation from LCP plants, defined as hydropower or non-conventional sources plants with lower than 20 MW capacity, owned by private companies and cooperatives. Fossil fuel thermal plants, coal or large-scale hydropower are defined as conventional sources, whose development is planned by ICE, according to the Law 449 and national energy policies. Law 7200 capped electricity generated by the private sector to 15 per cent of the total energy production.[13] Law 7508 increased the cap of private generation in 1995 to 30 per cent.[32] By mandate, ICE buys the energy from LCP plants, according to ARESEP tailored tariffs for these plants. ARESEP and ICE methodologies for the licensing process are defined in the Law 7200 Regulation.[23]

In 2003, Law 8345 authorized public services distribution companies to use available energy sources in the country for supplying the electrical demand in their coverage areas. The law defines explicit requirements for hydropower projects licensing for these companies.[24] In 2007, the Government of Costa Rica assumed a self-imposed commitment of becoming the first carbon neutral country in the world by 2021. The commitment was publicly stated in the Conference of Parties (COP) 15 in Copenhagen in 2009.[33]

In 2015, at COP 21, Costa Rica acted as a key leader in the Paris Agreement. In its Nationally Determined Contributions (NDC), Costa Rica reaffirmed the commitment towards carbon neutrality in 2021 and pledged to maintain the carbon emissions cap below 9.4 million-ton CO_2 eq in 2030, on the global path towards limiting global warming to below 2°C.[34] In 2016, the Legislative Assembly ratified the agreement.[35]

National renewable energy policies are defined in the National Energy Plans, under the guidelines of the National Development Plan, established by the Government. The Plan contains short, medium and long-term goals, with defined time limits and responsible institutions.[36] In 2015, a plan specific goal towards distributed generation was achieved, with the Executive Order 39220. This new policy regulates self-supply distributed generation with renewable energy sources, using simple net metering.[37]

ICE creates the Electric Generation Expansion Plans, in compliance with the national energy policies and specifically the National Energy Plan. ICE planning focuses on searching for a sustainable electrical development, ensuring low use of carbon fossils, diversifying renewable sources, lowering the cost of electricity and creating new electric generation investments in cooperative public-private schemes. Planned investments for the 2016-2035 period include mostly renewable sources adding up 1,944 MW, with temporary complements of 125 MW fossil fuel plants. Large-scale hydropower comprises 56 per cent of the renewable sources. Principal additions are the 306 MW Reventazón Power Plant, commissioned in 2016 and 650 MW Diquis Hydroelectric Project, planned for commissioning in 2026. Wind power and solar projects add 24 per cent and 5 per cent respectively. SHP contributes with 0.3 per cent, already commissioned in 2016.[7]

There is no specific policy addressing SHP or hydropower in general. Instead, energy plans focus on diversifying the available renewable sources, especially the non-conventional sources, in order to complement the seasonality of hydropower. The VII National Energy Plan 2015-2030 defines biomass, wind power and solar as non-conventional sources.

Barriers to small hydropower development

The available data suggests that there is a significant untapped potential for the development of SHP projects. The main barriers for future development are:

- Environmental – Municipal and Government moratoriums have been made arguing environmental concerns. Future developments should consider enhancing the sustainability of hydropower and further collaboration with stakeholders.
- Run-of-the-river seasonality – Nowadays the share of renewable energy is highly influenced by the hydropower generation pattern. SHP plants are mainly run-of-river thus increasing the surplus of hydropower resources in the rainy season and providing less energy in the dry season. Therefore, the diversification of the energy mix is required for providing renewable energy during low-season hydropower.[40]
- SHP Planning – The present report found that no comprehensive planning for SHP development exists. SHP planning should be considered in long-term renewable energy policies, in compliance with SEN requirements for run-of-the-river projects as stated above. This will lead to an organized and optimum development of SHP, which represents a more sustainable way to harness the untapped hydropower potential in the country.

References

1. INEC (2018). Buscador de Estadísticas. *INEC Website*. http://www.inec.go.cr/ (accessed February 7, 2018).
2. IMN (2008). *El Clima, Su Variabilidad y Cambio Climático en Costa Rica.* San José: MINAE, 2008.
3. Solano, Johnny, and Roberto Villalobos (2001). Aspectos Fisiográficos aplicados a un Bosquejo de Regionalización Geográfico Climático de Costa Rica. *Tópicos Meteorológicos y Oceanográficos*, no. 8 (June 2001): 26-39. https://www.imn.ac.cr/publicaciones.
4. UNESCO (2002). *Balance Hídrico Superficial de Costa Rica*. Montevideo: UNESCO, 2002.
5. ICE (2017). Informes y Boletines: Informe Mensual Diciembre 2017. *Centro Nacional de Control de Energía Website*. https://appcenter.grupoice.com/CenceWeb/CenceMain.jsj (accessed

February 19, 2018).
6. ICE (2017). Costa Rica alcanza 300 días de generación eléctrica 100% renovable en 2017. *Grupo ICE Ticoblogger Website.* http://grupoice.ticoblogger.com/2017/11/18/costa-rica-alcanza-300-dias-de-generacion-electrica-100-renovable-en-2017/ (accessed February 19, 2018).
7. ICE (2017). *Plan de Expansión de la Generación Eléctrica*. San José: ICE, 2017.
8. Gobierno Costa Rica (2018). Costa Rica logró mayor desarrollo de economía en América Latina durante los últimos cuatro años. *Gobierno CR Website*. http://gobierno.cr/tag/pib/ (accessed February 26, 2018).
9. WWF (2014). *Green Energy Leaders*. Gland: WWF, 2014.
10. WEF (2017). Global Energy Architecture Performance Index Report 2017. *World Economic Forum Website*. http://reports.weforum.org/global-energy-architecture-performance-index-2017/ (accessed February 19, 2018).
11. WEF (2018). Global Competitiveness Report 2017-2018. *World Economic Forum Website*. http://reports.weforum.org/global-competitiveness-index-2017-2018/ (accessed February 19, 2018).
12. Asamblea Legislativa de la República de Costa Rica (n.d.). *Ley 449 Creación del Instituto Costarricense de Electricidad*. San José: Asamblea Legislativa de la República de Costa Rica,1949.
13. Asamblea Legislativa de la República de Costa Rica (n.d.). *Ley 7200 Que Autoriza la Generación Eléctrica Autónoma o Paralela*. San José: Asamblea Legislativa de la República de Costa Rica,1990.
14. Arguedas, Diego (n.d.). Guanacaste, capital costarricense de la electricidad limpia. *Ojo al Clima Website.* https://ojoalclima.com/guanacaste-la-capital-costarricense-la-electricidad-limpia/ (accessed February 19, 2018).
15. Presidencia de la República de Costa Rica (n.d.). Hechos y Acciones Administración Solís Rivera: Instituto Costarricense de Electricidad. *Hechos y Acciones Administración Solís Rivera Website.* https://logros.presidencia.go.cr/ice/ (accessed February 19, 2018).
16. ICE (2018). Generación privada no abarata las tarifas eléctricas. *Grupo ICE Ticoblogger Website*. http://grupoice.ticoblogger.com/2018/01/12/generacion-privada-no-abarata-las-tarifas-electricas/ (accessed February 19, 2018).
17. Programa Estado de la Nación (2017). *Estado de la Nación 2017.* San José: Programa Estado de la Nación, 2017.
18. Jiménez, Marco (2018). *2018 Costa Rica Small Hydropower Database*: ICE, 2018
19. ICE (2010). *Revisión Estructural de Presas Electriona y Belén.* San José: ICE, 2010
20. Hoes, Olivier, Lourens J. J. Meijer, Ruud J. van der Ent and Nick C. van de Giesen (2017). Systematic high-resolution assessment of global hydropower potential. *PLoS ONE*, no 12 (February 2017): 1-10. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0171844
21. Mosier, Thomas, Kendra V. Sharp and David F. Hill (2016). The Hydropower Potential Assessment Tool (HPAT): Evaluation of run-of-river resource potential for any global land area and application to Falls Creek, Oregon, USA. *Renewable Energy*, no 97 (November 2016): 492-503. https://www.sciencedirect.com/science/article/pii/S0960148116305146.
22. ICE (2015). *Costa Rica: Matriz Eléctrica: Un Modelo Sostenible* Único *en el Mundo*. San José: ICE, 2015.
23. Presidencia de la República de Costa Rica (2012). Decreto Ejecutivo N°37124 MINAET Reglamento a Ley de la Generación Eléctrica Autónoma Paralela. *La Gaceta*, no 108 (June 2012). 116-127. https://www.imprentanacional.go.cr/pub/2012/06/05/ALCA72_05_06_2012.pdf.
24. Asamblea Legislativa de la República de Costa Rica (2003). *Ley 8345 Participación de las cooperativas de electrificación rural y de las empresas de servicios públicos municipales en el desarrollo nacional*. San José: Asamblea Legislativa de la República de Costa Rica,2003.
25. Madrigal, Luis (n.d.). Upala aprueba moratoria de cinco años a construcción de hidroeléctricas. *Elmundo.cr.* https://www.elmundo.cr/upala-aprueba-moratoria-de-cinco-anos-a-construccion-de-hidroelectricas/ (accessed February 19, 2018).
26. Presidencia de la República de Costa Rica (2015). Decreto Ejecutivo N° 39199 MINAE Salvaguarda Ambiental Para El Cauce Principal De Los Ríos Pacuare y Savegre. *La Gaceta*, no 191 (October 2015). https://www.imprentanacional.go.cr/pub/2015/10/01/COMP_01_10_2015.pdf.
27. ICE (2016). *Revisión Hidráulica del Proyecto Embalse* Río Piedras. San José: ICE, 2016.
28. ICE (2017). *Estudio de Factibilildad Proyecto Quinta Etapa de Abastecimiento del Acueducto Metropolitano Adenda 2 AyA.* San José: ICE, 2017.
29. Carbon Market Watch (2011). Mecanismo de Desarrollo Limpio en Costa Rica. *Carbonmarketwatch Website.* https://carbonmarketwatch.org/wp-content/uploads/2011/02/Presentacion_MDL_Costa-Rica.pdf (accessed February 19, 2018).
30. UNFCCC (n.d.). PoA 8950: Guacamaya Small Scale Hydropower Programme of Activities. *UNFCCC Website*. https://cdm.unfccc.int/ProgrammeOfActivities/poa_db/3WWHBI0SVEDK9NYTQJP4OCF7Z18LM6/view (accessed February 19, 2018).
31. ARESEP (2015). Fijación Tarifaria de Oficio Según La Metodología de Fijación de Tarifas Para Generadores Privados (Ley 7200) Que Firmen Un Nuevo Contrato de Compra y Venta de Electricidad con el ICE. *Alcance Digital La Gaceta*, no 2 (January 2015). https://www.imprentanacional.go.cr/pub/2015/01/12/ALCA2_12_01_2015.pdf.
32. Asamblea Legislativa de la República de Costa Rica (1995). *Ley 7508 Reformas de la Ley Que Autoriza la Generación Eléctrica Autónoma o Paralela*. San José: Asamblea Legislativa de la República de Costa Rica, 1995.
33. Programa Estado de la Nación (2013). *Carbono Neutralidad: Avances y Desafíos de cara al año 2021*. San José: Programa Estado de la Nación, 2013.
34. MINAE (2015). *Contribución Prevista y Determinada a Nivel Nacional de Costa Rica*. San José: MINAE, 2015.
35. Asamblea Legislativa de la República de Costa Rica (2016). *Ley 9405 Aprobación del Acuerdo de París.* San José: Asamblea Legislativa de la República de Costa Rica, 2016. Internal document
36. MINAE (2015). *VII Plan Nacional de Energía 2015-2030.* San José: MINAE, 2015.
37. Presidencia de la República de Costa Rica (2015). Decreto Ejecutivo N° 39220 MINAE Reglamento Generación Distribuida para Autoconsumo con Fuentes Renovables Modelo de Contratación Medición Neta Sencilla. *La Gaceta*, no 196 (October 2015). https://www.imprentanacional.go.cr/pub/2015/10/08/COMP_08_10_2015.html.

38. IMN (2012). *Inventario nacional de gases de efecto invernadero y absorción de carbono.* San José: IMN, 2012.
39. Asamblea Legislativa de la República de Costa Rica (2016). *Ley 9518 Incentivos y Promoción Para El Transporte Eléctrico.* San José: Asamblea Legislativa de la República de Costa Rica, 2016. Internal document.
40. International Renewable Energy Agency (IRENA) (2017). Electricity storage and renewables: Cost and markets to 2030. *IRENA Website*. Available from http://www.irena.org/publications/2017/Oct/Electricity-storage-and-renewables-costs-and-markets (accessed February 27, 2018)
41. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from: www.smallhydroworld.org. Accessed 15 April 2018
42. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org

2.2.3 El Salvador

Juan Jose Garcia Mendez, Superintendencia General de Electricidad y Telecomunicaciones

Key facts

Population	6,522,419[1]
Area	21,041 km² [2]
Climate	The climate in El Salvador is tropical and is characterized by its two seasons – a dry season from November to April and a rainy season from May to October. The annual average temperature was 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.[4]
Topography	The topography of El Salvador consists mainly of mountains with a narrow coastal belt and a central plateau. Approximately, 85 per cent of the land (interior highland) is comprised of the mountain range and central plateau, and the remaining 15 per cent (pacific lowlands) is comprised of coastal plains. The highest point in El Salvador is the peak El Pital, which rises at 2,730 metres above sea level.[3]
Rain pattern	There is a variation in rainfall between the driest and wettest months of approximately 227 mm. The average annual precipitation is 1,749 mm.[4]
Hydrology	El Salvador has eleven hydrographic regions that are delimited by the basins of the country's main rivers and are identified by the river's name. Among these regions, one of the most important is the "A" region or the Lempa River region, with an area of 10,082 km², which represents approximately 48 per cent of the national territory.[5]

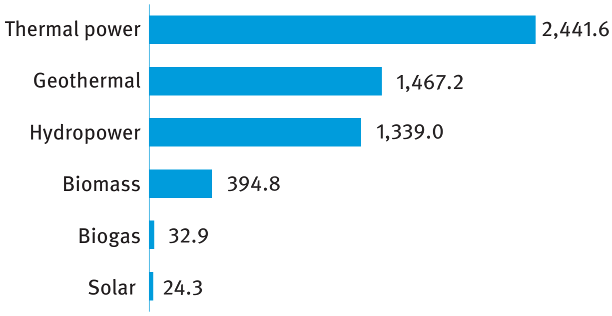
Electricity sector overview

The electricity sector is comprised of the wholesale electricity market and the retail electricity market. The first one is constituted by the Long-Term Contracts Market (CLP) and the Spot Market (MRS). In order to participate in the wholesale electricity market, the installed capacity of a power plant must be equal or greater than 5 MW and it can be interconnected 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 interconnected to the distribution network. Bilateral contracts can be signed in both markets (PPA, Power Purchase Agreement), to commercialize the electricity generated.[16]

The total electricity generation in both markets was 5,700 GWh; 43 per cent was generated with thermal resources, 26 per cent geothermal, 23 per cent hydropower, 7 per cent biomass, 0.6 per cent biogas and 0.4 per cent solar power (Figure 1).[12] It is important to consider that the biomass generation consists of sugar cane bagasse. Therefore, these power plants operate only during the sugar cane harvest season (zafra), which is during the dry season between November and April each year, and as such complements the seasonality of hydropower.[12]

As shown in Figure 1, the generation mix has an important renewable component, 57 per cent of the electricity generated in 2016 came from natural renewable resources and 43 per cent from fossil fuels. Nevertheless, the generation mix varies with the season and the pluviosity of the year.[12]

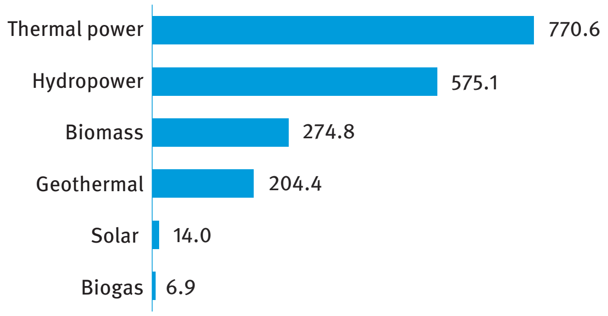
Figure 1.
Annual electricity generation by source in El Salvador (GWh)



Source: SIGET[12]

By December 2016, the overall installed capacity (wholesale and retail electricity market) was 1,846 MW. It included six resources – thermal (heavy fuel oil and diesel) with the largest share of 42 per cent, hydropower at 31 per cent, biomass (sugar cane bagasse) at 15 per cent, geothermal at 11 per cent, solar photovoltaic at 0.7 per cent and small-scale biogas (manure) at 0.3 per cent (Figure 2.). The increase in installed capacity compared to the *World Small Hydropower Development Report (WSHPDR) 2016* is due to an enhanced transparency of data, but also because of recent projects implemented in El Salvador. The Government has approved multiple initiatives, promoting renewable energy development. The use of photovoltaic resources and non-conventional renewable energy has substantially increased.[20] The maximum demand in 2016 was 1,093 MW.[12]

Figure 2.
Installed electricity capacity by source in El Salvador (MW)



Source: SIGET[12]

In El Salvador, 96 per cent of households have access to electric lighting service. In the urban area 98 per cent have access to this service, while in the rural area this rate is 92 per cent.[6] However, during the last five years, through an agreement between the distribution companies and the Regulatory Entity, the distribution companies are developing electrification projects in areas with no electricity access.

El Salvador is part of the Regional Electricity Market (MER) and thus adopted the rules of the "Framework Treaty of the Central American Electricity Market", approved by representatives of the Governments of 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) that carry out international electric power transactions in the Central American region.[7] All the member countries are interconnected through the SIEPAC transmission network.

Historically, as in many other countries in Latin America, the energy sector was first developed by the state. The electricity market was vertically integrated, which means that the activities of generation, transmission, distribution, commercialization and long-term planning of the energy sector were controlled and regulated by the state.[7] Due to several policies implemented by the Government in the 1990s, the electricity market, among others, underwent reforms of laws and regulatory frameworks. The reforms redefined the role of the state in the development and long-term planning of the market. 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.[7]

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.[7]

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. It is relevant to point out that the CNE is constituted by the minister/vice-minister of the government departments related to the different aspects of the energy sector's development. The departments involved are the Ministry of Economy, Technical Secretariat of the Presidency, Ministry of Treasury, Ministry of Public Works, Ministry of Environment and Natural Resources and Consumer Protection Agency. Any initiative that affects the energy sector is thoroughly discussed and analyzed before its implementation.[7]

Nowadays, the electricity sector is comprised of the following agents:

- Electricity generating companies, which produce electricity from the several available resources in the country;
- Transmission agent (ETESAL), private enterprise responsible for the planning of the expansion, construction of new extensions and maintenance of the national transmission network;
- Electricity distribution companies, private company owners and operators of the facilities whose purpose it is the delivery of electrical power in low voltage networks;
- Electricity trader, 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;
- ISO/IMO, market and system operator (UT), in charge of operating the transmission system, maintaining the security of the system and ensuring a defined minimum quality of the services and supplies. It also operates the wholesale electric power market;
- The regulatory entity (SIGET) is the competent entity to apply the laws and regulations that govern the Electricity and Telecommunications sectors;
- National Council of Energy (CNE), responsible for establishing the long-term energy policy and strategy to promote the efficient development of the energy sector.

The electricity grid is comprised of the high-voltage transmission network (≥115 kV) and the mid/low-voltage distribution network (<115 kV). The transmission network is constituted by 40 lines at 115 kV, with a combined length of 1,072.5 km, and four lines at 230 kV that interconnect the transmission system of El Salvador with Guatemala (14.6 km) and Honduras (92.9 km).

The distribution network is operated by eight companies and supply electricity at different voltages. The overall length of the distribution lines is 48,233 km, and the system supplies electricity to 1,747,000 end users. According to CNE, as a result of the strategic guidelines of the National Energy Policy regarding the development of renewable energy, it is expected to have an increase in the installed capacity, reaching a total of 2,475 MW by 2025. This will represent a growth of 34 per cent, in comparison to 2016.[8]

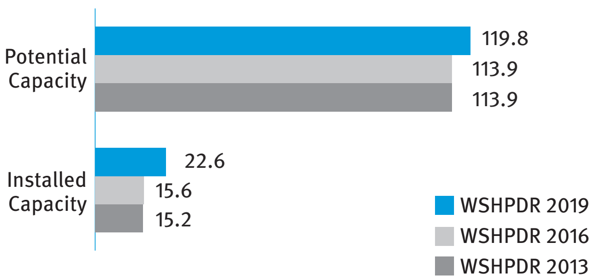
In June 2016, the average electricity tariff in the residential, commercial and industrial sectors was the lowest among the eight member countries of the Central American Integration System (SICA).[9] In El Salvador, the tariff rates are approved by SIGET annually and are adjusted and approved by the same institution quarterly. The average electricity tariff for industry was 0.14 US$/kWh, for retail 0.15 US$/kWh and residential 0.14 US$/kWh.[21]

Small hydropower sector overview

The country's definition for small hydropower (SHP) is a hydroelectric power plant with an installed capacity less than or equal to 20 MW.[10] In December 2016, the total installed hydropower was 575.1 MW of which 22.6 MW (4 per cent) is SHP under 10 MW (Table 1).[12] For small hydropower plants up to 10 MW, the potential capacity was at least 119.8 MW and could be developed by the year 2026.[10] There are feasibility studies recently made available and conducted previously as part of the El Salvador National Plan for the Development of Sustainable Energy.[17] Figure 3 offers the information on small hydropower up to 10 MW potential and installed capacity, while Figure 4 for SHP up to 20 MW.

The slight increase in small hydropower installed capacity and potential since the *WSHPDR 2016* is due to the modernization and refurbishment work on certain plants, which resulted in an increase in their capacity. One relevant example is the hydropower plant San Luis I, which initially had only 0.6 MW of installed capacity (now 1.1 MW).[18]

Figure 3.
Small hydropower capacities (up to 10 MW) 2013/2016/2019 in El Salvador (MW)



Source: *WSHPDR 2013*,[13] *WSHPDR 2016*,[14] Landaverde,[17] CECSA[18]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2016*.

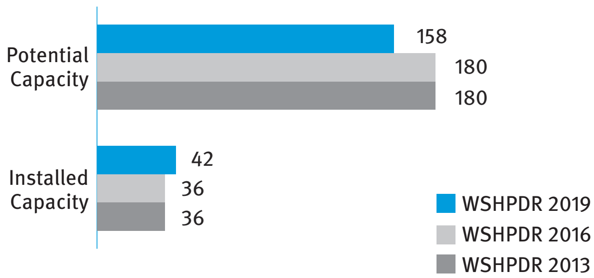
Table 1.
Installed capacity of SHP under 10 MW

Hydropower plant	*Installed capacity (MW)*
Sonsonate	0.150
Cucumacayán	2.800
Bululú	0.680
San Luis I	1.100
Cutumay Camones	0.300
Río Sucio	4.800
Milingo	1.842
Atehuesias	0.600
San Luis II	0.740
Nahuizalco	2.800
Papaloate	2.000
La Calera	1.450
Juayúa	2.450
Venecia Prusia	0.750
Miracapa	0.034
La Chacara	0.025
Junquillo	0.018
El Calambre	0.058
Total	**22.6**

Source: SIGET[12]

Figure 4 below offers data on plants up to 20 MW, the local definition for small hydropower. The decrease in potential since 2016 is the result of feasibility studies conducted made available recently. The potential for plants up to 20 MW is at least 158 MW.[19]

Figure 4.
Small hydropower capacities (up to 20 MW) 2013/2016/2019 in El Salvador (MW)



Source: MARN,[10] *WSHPDR 2013*,[13] *WSHPDR 2016*,[14] SIGET[19]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

In 2017, three concession permits to build SHP plants were given (San Simón I, 0.23 MW; San Simón II, 0.4 MW and Velesa Energy, 0.12 MW). The plants will come into operation in 2019. According to the Master Plan for the Development of Renewable Energy (CNE, 2012), the overall potential capacity of hydropower in El Salvador (which was estimated through the technical potential method) is 2,235 MW.

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.[11] Several actions have been taken since the implementation of the NEP to foster the development of renewable energy generation projects.

To facilitate the implementation of renewable energy generation projects, several adjustments were made in the legal and regulatory frameworks of the electricity and environmental sectors, and to taxation regulations. These adjustments include reforms of the General Law of Electricity and in the Environmental Law. Among all the laws and regulations that affect the development of these projects, the most relevant are:

- The Law of Fiscal Incentives for the Promotion of Renewable Energy in the 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 of the Energy Sector. Its purpose is to determine if a project would need 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 these 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.

Barriers to small hydropower development

Despite all efforts to foster the development of renewable energy projects (including SHP) for the diversification of the energy mix, the country still faces several technical, institutional, social and economic barriers. In order to fully achieve the objectives stated in the NEP and reach the level of development estimated in the Master Plan, understanding and tackling the following barriers is essential.

- A lack of accurate hydrological data;
- The high cost of available hydrological data;
- A long, undetermined timeframe to obtain concession permits from the congress;
- Possible social opposition to the construction of hydropower plants;
- Insecurity and violence affecting project development areas;
- Few or limited domestic options for financing small hydropower plants.

To conclude, El Salvador has taken important steps at both a regulatory and institutional level to promote the development of hydropower plants (and of renewable energy in general). Nevertheless, structural issues that might slow the development still exist, one of them being the uncertainty in the time taken by the congress to grant concession permits. Another relevant barrier that affects the mid and long-term development of small hydropower plants is the level of insecurity existent in project construction areas.

References

1. DIGESTYC (2017). Encuesta de Hogares de Propósitos Múltiples 2016. May 2017: 1-2. Available from http://www.digestyc.gob.sv/index.php/temas/des/ehpm/publicaciones-ehpm.html
2. DIGESTYC (2017). Encuesta de Hogares de Propósitos Múltiples 2016. May 2017: 2-3. Available from http://www.digestyc.gob.sv/index.php/temas/des/ehpm/publicaciones-ehpm.html
3. Central Intelligence Agency (CIA) (2017). *The World Factbook*. Available from https://www.cia.gov/library/publications/the-world-factbook/geos/es.html (Accessed February 9, 2018).
4. García, Luis et al. Caracterización de condiciones meteorológicas en El Salvador. Ministerio de Medio Ambiente y Recursos Naturales. Available from *http://portafolio.snet.gob.sv/digitalizacion/pdf/spa/doc00252/doc00252.htm.* (Accessed February 9, 2018).
5. Ministerio de Agricultura y Ganadería (MAG) (2013). *Cartografía de Cuencas Hidrográficas de El Salvador*. Available from http://cartografia.mag.gob.sv/ (Accessed February 9, 2018).
6. DIGESTYC (2017). Encuesta de Hogares de Propósitos Múltiples 2016. May 2017: 36. Available from http://www.digestyc.gob.sv/index.php/temas/des/ehpm/publicaciones-ehpm.html
7. Comisión Regional de Energía Eléctrica (CRIE) (2017). Available from http://crie.org.gt/wp/que-es-el-mer/
8. Palacios, Herbert (2017). Estado Actual De Las Energías Renovables En El Salvador. Taller Fomento del Desarrollo del Mercado de Energía Renovable en Centroamérica September 2017. San José. Costa Rica.
9. CEPAL (2017). Estadísticas del subsector eléctrico de los países del Sistema de Integración Centroamericana (SICA) 2016. December 2017: Available from https://www.cepal.org/es/publicaciones/42720-estadisticas-subsector-electrico-paises-sistema-la-integracion-centroamericana
10. Ministerio De Medio Ambiente Y Recursos Naturales (MARN) (2012). ACUERDO No. 33. Categorización de actividades, obras o proyectos de generación de electricidad a partir del aprovechamiento del recurso hídrico. May 2012. Available from http://www.marn.gob.sv/descarga/documento-de-categorizacion-de-actividades-obras-o-proyectos-de-energia-renovable-2/?wpdmdl=18006&ind=goWwn9mv3F7kJ4b5NnnCvTbHBRNaZsgAXxli9nqw0FVFAwBpPQIN1C2xSFtf5ax5YXkq8e_BqkqkcxMmAa8vuSCiqo2WzbrK0vRI4_qBPvp7OUf_QCswiXUYWAOKuIxi9LO2CLbx9Ry9_-WxfZ5fXg
11. Government of El Salvador (2017). Política Energética Nacional. Available from http://www.cne.gob.sv/wp-content/uploads/2017/09/poltica_nacional_de_energia.pdf

12. Superintendencia General de Electricidad (SIGET) (2017). Electricity Generation and Installed Capacity in El Salvador. Document not yet made official by the Government of El Salvador
13. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
14. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
15. International Renewable Energy Agency (2017). Renewable Energy Statistics 2017. Available from http://www.irena.org
16. The United States Trade and Development Agency (2011). Definitional Mission for Latin America and the Caribbean Regional – Renewable Energy Projects in Central America (Costa Rica, El Salvador, Guatemala, Honduras, and Panama). Constant Group LLC. Solicitation Number RFQ-CO2009510001
17. Landaverde, J. (2013). Country Report: El Salvador. Ingendehsa.S.A de C.V. *Note: Site of Ingendehsa was suspended, therefore the report is no longer available online. However, the study was conducted under the approval of the Government of El Salvador and published in an unofficial report, in 1991 Estudio Conjunto CEL/UCA Sobre Pequeñas Centrales Hiroelectricas En El Salvador
18. CECSA El Salvador (2011). Internal data. Gobierno de El Salvador
19. Superintendencia General de Electricidad (SIGET) (2017). Potential Capacity of Small Hydropower up to 20 MW. Internal data. El Salvador
20. Gobierno de El Salvador (2017). Proyectos con Energias Renovables. Available from http://energiasrenovables.cne.gob.sv/index.php?option=com_content&view=article&id=37&Itemid=65
21. Superintendencia General de Electricidad (SIGET) (2018). Tarifas de Electricidad El Salvador. Available from https://www.siget.gob.sv/?wpdmact=process&did=NDExLmhvdGxpbms

2.2.4

Guatemala

Jonas Dobias, Ministry of Energy and Mines

Key facts

Population	16,176,133[1]
Area	108,889 km² [2]
Climate	There are three climate zones in Guatemala. Daytime temperatures can reach as high as 40 °C and temperatures at night rarely drop below 20 °C in the tropical lowlands. Approximately 1,000 to 2,000 meters above sea level is the temperate zone, with day-time temperatures rarely exceeding 30 °C. Day-time temperatures in the cool zone are only slightly lower than in the temperate zone. However, the nights are rather cold and temperatures occasionally drop below freezing.[2]
Topography	A roughly 48 km width tropical plain parallels the Pacific Ocean. Guatemala also has a piedmont region, which rises to altitudes of 90 to 1,370 metres. Nearly two-thirds of the country lies above these regions, in a mountainous, volcanic area stretching north-west and 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]
Rain pattern	The average annual rainfall in Guatemala is 1,232 mm. Precipitation varies across the dry and the wet seasons of the country, from 100 mm to 500 mm per month.[2,19]
Hydrology	In terms of hydrology, the country can be divided in 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 ten basins. There are ten basins in the Gulf of Mexico region as well, home to the most abundant rivers in the country.[2]

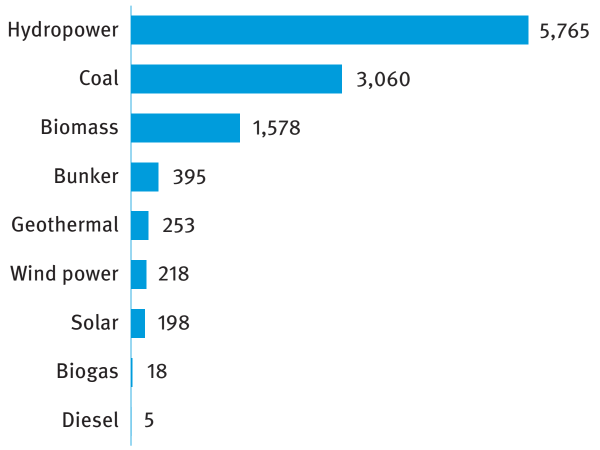
Electricity sector overview

In 2017, the total electricity generation was 11,490 GWh, of which 1.7 GWh were exported to the Regional Energy Market (MER), and 0.03 GWh to Mexico, while 0.002 GWh were imported from MER and 0.8 GWh from Mexico. Hydropower was the main source of electricity production in Guatemala, accounting for around 50 per cent of the total generation in 2017. The total installed capacity was 4,072 MW and 3,350 MW was available capacity, with 56 per cent from thermal (coal, diesel, bunker fuel, geothermal and biomass), 39 per cent hydropower, 3 per cent solar and 2 per cent wind power.[3]

The electrification rate is 91.1 per cent. However, there is a big gap between the main urban regions and those with a high rate of rural population. Guatemala is divided into 22 regions and each region into municipalities. There is a total of 340 municipalities in the country. Fifteen regions have a coverage rate of above 95 per cent, three between 90 and 95 per cent, three between 85 and 90 per cent and one of 44 per cent (Figure 2).[3]

The lowest electricity coverage is located in the North, where the lowest economic indicators are shown. The Inter-American Development Bank has approved a loan of US$ 55 million to assist in increasing electricity access, improving connectivity and expanding the coverage of the national electricity service. As a result of this programme, the electrification coverage is expected to reach 92.9 per cent by 2019 through investments in the grid and the installation of isolated systems using renewable energy sources.[2]

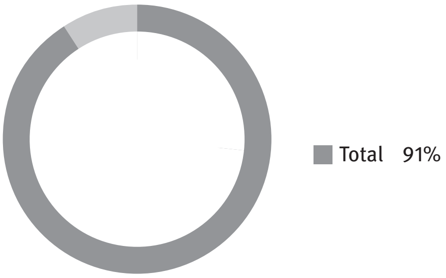
Figure 1.
Annual electricity generation by source in Guatemala (GWh)



Source: AMM[3]

To increase the electricity coverage in rural areas not connected to the national grid, the Ministry of Energy and Mines (MEM), through the National Institute for Electrification (INDE), are implementing the Rural Electrification Plan (PER), based on Article 47 of the General Electricity Law of 1997. The main sources of energy are focused on micro-hydropower development and solar photovoltaic (PV) systems. In this area, the Latin American Energy Organization (OLADE), the United Nations Development Programme (UNDP) and other international aid and non-governmental organizations (NGOs) are also significant actors.[4]

Figure 2.
Electrification rate in Guatemala



Source: AMM[3]

Central America is interconnected through the Central American Electrical Interconnection System (SIEPAC). Guatemala is connected to El Salvador and Honduras. The infrastructure consists of a transmission line 1,790 km long, of 230 kV, with 28 access points and 15 electrical substations through six countries: Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama. It will have the capacity to transport up to 300 MW.[5] The energy power and electricity transactions take place in the MER and the dispatching operations are done by the Regional Operator Entity (EOR).[6] In addition, Guatemala is interconnected to Mexico through a transmission line 103 km long, of 400 kV and two substations.[7]

The electricity sector planning in Guatemala is overseen by the MEM. The National Electricity Commission is in charge of regulation, while energy dispatching is operated by an NGO, the Administrador del Mercado Mayorista (AMM).[2] The electricity grid is made up of generation (electric power and electricity), transportation (to transfer the electricity from the generation system to the distribution grid) and distribution (bringing the electricity to the final users). The generation includes hydropower, vapor turbines, gas turbines, internal combustion, geothermal, solar and wind power systems. Hydropower and geothermal generators make use of public domain assets and are thus required to have authorization from MEM. The INDE, a state-owned company, 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 8 transmission companies, the largest being operated and owned by INDE (more than 75 per cent of the total), while the other 7 are privately-owned, from which one of them owns the regional line of SIEPAC. There are 19 distribution companies. One belongs to INDE and provides service 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 Government plans to develop the electricity sector are enclosed in three documents:

- Energy National Plan 2017-2032, which is based on three axes: (i) sustainable use of natural resources; (ii) energy efficiency; and (iii) emissions reduction of greenhouse effect;[9]
- Expansion Plan for the Generation and Transportation System 2018-2032, which, according to the Regulation of the Wholesale Market Administrator in Article 15, should have a period of 10 years and must be updated every two years;[10]
- Energy Policy 2013-2027, which is based on six axes: (i) competitive prices for electric supply assurance; (ii) competitive prices for fuels supply assurance; (ii) local supply from exploration and exploitation of the oil reserves; (iv) energy efficiency; and (v) reduction of log use in the country.[11]

The electricity tariffs are set by the National Commission for Electric Energy (CNEE) every five years, and they are adjusted every three months based on the energy bought by the distributor, the dollar exchange rate, the fuel prices and energy demand. In Guatemala, households that consume less than 100 kWh per month receive a subsidy from the state, through INDE. For other users the current price is 0.151 US$/kWh.

Table 1.
Electricity prices in Central America (US$/kWh), September 2017

Consumption (kWh)	*Guatemala*	*El Salvador*	*Honduras*	*Nicaragua*	*Costa Rica*	*Panama*
0-60 kWh	0.069	0.123	0.17	0.142	0.134	0.105
61 - 88 kWh	0.103	0.199	0.17	0.157	0.134	0.112
89 - 100 kWh	0.148	0.198	0.17	0.161	0.134	0.113
101 - 300 kWh	0.151	0.198	0.17	0.203	0.134	0.12
301- 500 kWh	0.151	0.204	0.17	0.223	0.199	0.18
>501 kWh	0.151	0.206	0.17	0.299	0.221	0.196

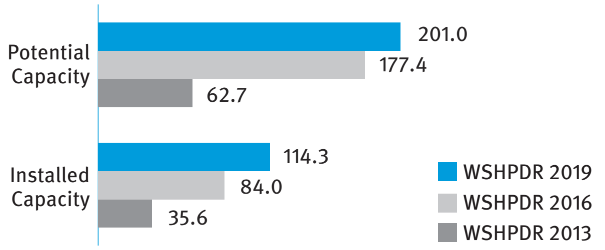
Source: MEM[14]

Small hydropower sector overview

In Guatemala, the definition of small hydropower (SHP) refers to plants that have an installed capacity below 5 MW. The difference between the development of hydropower above 5 MW and below is that the latter does not make use of public domain assets, and thus does not need an authorization from MEM. However, SHP plants must be registered (Article 8, General Electricity Law).[12] At the same time, these projects have to fulfil some requirements (Environmental Impact Assessment and Environmental Flow Design, among others) from the Ministry of Environment and Natural Resources (MARN) to obtain an Environmental Licence. They have to fulfil other requirements from different institutions; for example, localization and forestry management from the

National Committee for Protected Areas (CONAP) and National Institute for Forestry (INAB) respectively, along with some connection authorizations or studies from CNEE, AMM and INDE.[8]

Figure 3.
Small hydropower capacities 2013/2016/2019 in Guatemala (MW)



Source: *WSHPDR 2013*,[20] *WSHPDR 2016*,[2] MEM[14]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

SHP plants and renewable systems in Guatemala (< 5 MW) can be connected to the national grid, or they can be connected directly to the companies operating the distribution grids. The latter is regulated by the Technical Norm for Generation of Renewal Energy and Self-Producers with Energy Excess (NTGDR).[13] At the end of 2017, there were a total of 74 SHP plants registered as NTGDR in MEM; 58 are currently operating (114.32 MW), 37 are registered but not operating (84.73 MW) and there is one pending registration (1.9 MW). The increase in installed capacity compared to the *World Small Hydropower Development Report (WSHPDR) 2016* is due to more specific data being recently made available by the Government of Guatemala (Figure 3). The SHP potential capacity is not established in Guatemala; however, during the 1970s and 1980s, the Master Hydropower Plan for the country was produced, and it estimated that the SHP capacity was around 5,000 – 6,000 MW.[14] This capacity is only theoretical, and no updated data on potential is available. Based on the operating, registered and pending registration SHP plants, it can be assumed that there is at least 201 MW of SHP potential.

Moreover, there are other micro-hydropower plants not connected to the grid that are not inventoried, with most of them located in rural areas and operated by small 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 the lack of maintenance and, in some cases, they are damaged due to natural catastrophes, such as floods, resulting from hydrological extreme events. These plants need to be re-constructed or refurbished and the former installed capacity should be increased.[14]

One main financial mechanism for the development of SHP in the country comes from the alliance of three entities: Central American Bank for Economic Integration (CABEI), the European Union as part of its Investment Facility in Latin America (LAIF), and the Government of Germany through the German Development Bank (KfW). Shortly, they will begin a second phase to promote renewable energy projects (solar, hydropower, wind, biomass and biogas) under 5 MW installed capacity, for which they have a reimbursable fund of around US$ 40.0 million. The programme is called Green Micro, Small and Medium Enterprises (MIPYMES Verde). Additionally, the programme will also have a pocket of non-reimbursable funds, which will be used to promote the development of small renewable energy and energy efficiency projects and their financing through Central American financial institutions.

The financial funds are managed by CABEI, which grants credits to final beneficiaries through local financial banks. The beneficiaries are companies that qualify under MIPYMES, energy developers and investors for environmental-friendly energy and energy efficiency programmes. The maximum amount of financing for a project is US$ 5 million, for a maximum period of time of 10 years, depending on the project. MIPYMES Verde is a regional programme.[15]

Renewable energy policy

The general renewable energy development plan of Guatemala is the Energy Policy 2013-2027. Plans for the promotion, use and development of renewables in electricity generation are included. Diversifying electricity generation through prioritization of renewable resources is one of the main goals. The long-term goal is generating 80 per cent of electricity from renewables, however there is no date specified for achieving this target.[2] Planned actions include the following:

- New studies on the renewable energy potential of the country will be conducted and old data updated;
- Hydropower, geothermal, solar, wind and biomass energy will be promoted, alongside other available clean energy sources;
- Technological innovation and development will be encouraged and promoted, and steps will be taken to ensure the existent workforce in the energy sector is appropriately trained.

Other objectives include creating a Master Plan for the development of renewable energy and promoting investments in the production of renewables plants amounting to 500 MW.[2]

Geothermal power potential estimates in the country vary from 400 to 4,000 MW, while biomass can be estimated at approximately 500 MW. Waste products can generate another 5 MW. Between 2019 and 2022, it is estimated that solar PV power can be developed at a rate of 20 MW per year.[2]

The first axis of the Energy National Plan 2017-2032 established an additional installed capacity of 6,102 MW to generate 16,153 GWh for 2032. The candidate generators are described in Table 2, where renewable energies are prioritized.

One of the plan's actions is to implement a methodology for consulting local populations, based on the International Labour Organization's "C169, Indigenous and Tribal Peoples Convention".[9]

Table 2.
Planned installed capacity for 2032

Resource	*Number of projects*	*Installed capacity (MW)*	*Share of total capacity (%)*
Hydropower	66	3,550	58
Geothermal	3	300	5
Solar power	8	187	3
Wind power	3	101	2
Hybrid	4	316	5
Bunker fuel	4	445	7
Coal	2	600	10
Natural gas	4	603	10
Total	**92**	**6,102**	

Source: Energy National Plan 2017-2032,[9] MEM[14]

Another action is to promote the "Law of Incentives for Renewable Energy Development", which exempts custom tariffs for equipment and machinery used for renewable energy generation. It also exempts tax payments for the first ten years of operation.[16]

The second axis focuses on the energy efficiency, and the third axis' goal is to achieve a 29.2 per cent reduction of greenhouse gases emissions equivalent to 16.82 million tons of CO_2 by 2032.

The renewable energy plans and policies respond to the Guatemalan Climate Change Framework Law (*Ley Marco para Regular la Reducción de la Vulnerabilidad, la Adaptación Obligatoria ante los Efectos del Cambio Climático y la Mitigación de los Gases de Efecto de Invernadero*) and the National Policy on Climate Change.[17,18] They also respond to international agreements, such as the United Nation Framework Convention on Climate Change, the Paris Agreement and the Nationally Determined Contributions (NDCs).

Barriers to small hydropower development

Some of the barriers for the development of SHP and hydropower in general are the following:

- Environmental and social opposition to the development of hydropower, for which the MEM has developed a methodology for consulting local populations based on the International Labour Organization's "C169, Indigenous and Tribal Peoples Convention";[9]
- 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-the-grid hydropower in rural communities, where international cooperation and assistance is the main funding source.

References

1. Instituto Nacional de Estadística (2015). Indicadores Sociodemográficos. Available at: https://www.ine.gob.gt/index.php/estadisticas/tema-indicadores
2. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
3. Administrador del Mercado Mayorista (2018). Available at: http://www.amm.org.gt/portal/
4. Memoria de Labores, Dirección General de Energía (2015). Ministerio de Energía y Minas. Available at: http://www.mem.gob.gt/wp-content/uploads/2015/06/MEMORIA-DE-LABORES-DGE-2015-IV-Trimestre-al-7-12-15-ELECTRIFICACION-RURAL.pdf
5. Empresa Propietaria de la Red (2018). Available at: https://www.eprsiepac.com/contenido/descripcion-linea-siepac/
6. Ente Operador Regional (2018), Available at: http://www.enteoperador.org/
7. Sistema de Interconexión Eléctrica de los Países de América Central (2018). Available at: http://www.proyectomesoamerica.org/joomla/index.php?option=com_content&view=article&id=172
8. Mercado de Energía Eléctrica: Guiá del Inversionista (n.d.). Comisión Nacional de Energía Eléctrica. Available at: http://www.cnee.gob.gt/pdf/informacion/GuiadelInversionista2015.pdf
9. Plan Nacional de Energía 2017-2032 (2017). Ministerio de Energía y Minas. Available at: http://www.mem.gob.gt/wp-content/uploads/2017/11/Plan-nacional-de-energia.pdf
10. Plan de Expansión del Sistema de Generación y Transporte 2018-2032 (2018). Ministerio de Energía y Minas. Available at: http://www.mem.gob.gt/planes-de-expansion-del-sistema-de-generacion-y-transporte/
11. Política Energética 2013-2027. Ministerio de Energía y Minas. Available at: http://www.mem.gob.gt/wp-content/uploads/2013/02/PE2013-2027.pdf
12. Ley General de Electricidad (Decreto 93-1996). Ministerio de Energía y Minas. Available at: https://www.mem.gob.gt/wp-content/uploads/2012/06/2.1_Ley_General_de_Electricidad.pdf
13. Norma Técnica de Generación Distribuida Renovable y Usuarios Autoproductores con Excedencia de energía (Resolución CNEE 227-2014). Comisión Nacional de Energía Eléctrica: Available at: http://www.cnee.gob.gt/estudioselectricos/Normas%20Tecnicas/08%20NTGDR.pdf
14. Ministerio de Energía y Minas (MEM) (2018). Non-published data of the Ministry of Energy and Mines 2018.
15. Banco Centroamericano de Integración Económica (2018). Iniciativa MIPYMES Verdes. Available at: https://www.bcie.org/finanzas-para-las-mayorias/programas-de-mipyme/iniciativa-mipymes-verdes/
16. Ley de Incentivos para el Desarrollo de Proyectos de Energía Renovables (Decreto 52-2003). Ministerio de Energía y

Minas. Available at: http://www.mem.gob.gt/wp-content/uploads/2012/05/2.3-Ley-y-Reglamento-de-Incentivos-de-Energia-Renovables.pdf
17. Ley Marco para Regular la Reducción de la Vulnerabilidad, la Adaptación Obligatoria ante los Efectos del Cambio Climático y la Mitigación de los Gases de Efecto de Invernadero (Decreto 7-2013). Ministerio de Ambiente y Recursos Naturales. Available at: http://www.marn.gob.gt/Multimedios/415.pdf
18. Política Nacional de Cambio Climático (2009). Ministerio de Ambiente y Recursos Naturales. Available at: http://www.marn.gob.gt/Multimedios/56.pdf
19. Climate data (2017). Climate: Guatemala. Available from https://www.climate-data.org
20. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from: www.smallhydroworld.org. Accessed 15 April 2018

2.2.5 Honduras

Elsia Paz, Associacion Hondureña de Energia Renovable (AHER); and International Center on Small Hydro Power (ICSHP)

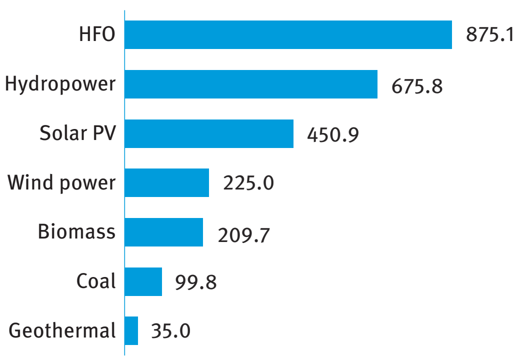
Key facts

Population	9,265,067[1]
Area	112,491 km[2]
Climate	In Honduras, the climate is subtropical in the lowlands and temperate in the mountain areas. The warmest month is May, with an average temperature of 25 °C, while the coolest month is January at 22 °C.[2]
Topography	The terrain is mostly mountainous in the interior with narrow coastal plains. The highest point is Cerro Las Minas at 2,870 metres. Approximately 80 per cent of the territory is 600-2,850 metres above sea level and 15 per cent is between 150 and 600 metres above sea level. Roughly 20 per cent consists of low coastal valleys along the Caribbean Sea and the dry plains along the Pacific coast.[2]
Rain pattern	The average annual rainfall is 1,470 mm. The rainy season is from May to November, with regional variations. Hurricanes and floods are common along the Caribbean coast.[2]
Hydrology	Honduras is a water-rich country. The most important river is the Ulúa, which flows 400 km to the Caribbean Sea through the economically important Valle de Sula. Numerous other rivers drain through the interior highlands and empty north into the Caribbean Sea. These rivers are important, not as transportation routes, but due to the broad fertile valleys they have produced. Rivers also define approximately half of the country's international borders. The Río Goascorán, flowing to the Golfo de Fonseca, and the Río Lempa define part of the border between El Salvador and Honduras. The Río Coco marks approximately half of the border between Nicaragua and Honduras.[2]

Electricity sector overview

In 2017, the installed electricity generating capacity in Honduras was 2,571 MW, which consisted of heavy fuel oil (HFO) fired power plants (34 per cent), hydropower (26 per cent), solar photovoltaics (PV) (18 per cent), wind power (9 per cent), biomass (8 per cent), coal-fired power plants (4 per cent) and geothermal power (1 per cent) (Figure 1).[3]

Figure 1.
Electricity installed capacity by source in Honduras (MW)

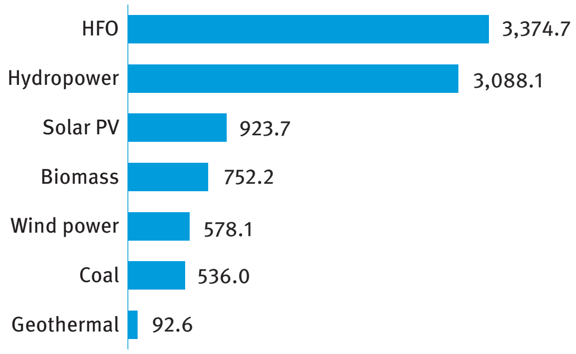


Source: ENEE[3]

The total generation of electricity in 2017 was 9,345 GWh, of which HFO accounted for 36 per cent, hydropower 33 per cent, solar PV 10 per cent, biomass 8 per cent, wind power 6 per cent, coal 6 per cent and geothermal power 1 per cent (Figure 2). A further 328 GWh was imported. The greatest share of electricity (approximately 40 per cent) is generated by privately owned thermal power plants.[3] The maximum demand in 2017 was 1,560.5 MW, which was observed in April of that year.[3] Of the 6,200 GWh supplied into the national electricity system, the residential and the commercial sectors consumed 40 and 27 per cent, respectively.[3] In 2016, approximately 88 per cent of the population had access to electricity nationwide, while in rural areas the electrification rate stood at 72 per cent.[4]

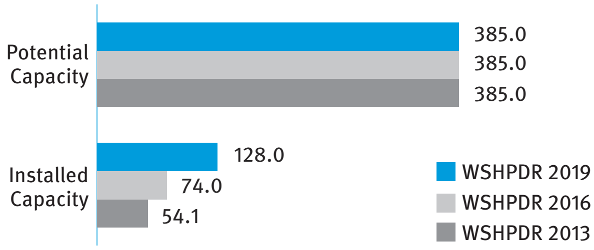
According to the Electricity Law of 1994, the highest authority in the country responsible for formulating policies for the energy sector is the Energy Cabinet. The Ministry of Natural Resources and Environment of Honduras (SERNA) is responsible for extending environmental licences for the sector. The Regulatory Commission for Electric Energy (CREE) is a regulatory authority in charge of the electric energy subsector and functions under SERNA. ENEE is under the jurisdiction of SERNA but is regulated by CREE.[5,6]

Figure 2.
Annual electricity generation by source in Honduras (GWh)



Source: ENEE[3]

Figure 3.
Small hydropower capacities up to 10 MW 2013/2016/2019 in Honduras (MW)



Source: ENEE,[3] *WSHPDR 2016*,[6] CIF,[9] *WSHPDR 2013*[10]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019.*

The General Law of the Electric Industry of 2014 allowed for the liberalization of the electricity market in Honduras. Moreover, it allows for the export and import of energy, creating new business opportunities, as well as direct sales of electricity to qualified consumers. CREE was appointed in June 2015.[6,7]

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. In May 2018, prices per kWh for residential consumers ranged from HNL 1.64 (US$ 0.07) to HNL 4.31 (US$ 0.18) depending on consumption and voltage.[8]

Small hydropower sector overview

Small hydropower (SHP) is defined in Honduras as hydropower plants with a capacity up to 30 MW. In March 2018, there were 42 SHP plants up to 30 MW with a combined installed capacity of 301.8 MW.[3] Only three of these plants were state-owned, while the remainder were privately owned. In the capacity range up to 10 MW, there were 33 SHP plants with a combined capacity of 128 MW.[3] Of these only one was state-owned. These plants ranged in capacity from 0.5 MW to 10 MW (Table 1).[3]

The total SHP potential up to 10 MW is approximately 385 MW, with an estimated potential generation of 470.2 GWh/year.[9] In comparison with data from the *World Small Hydropower Development Report (WSHPDR) 2016,* the installed capacity has increased by 73 per cent based on new capacities and more accurate data, while the potential remained unchanged (Figure 3).

The total hydropower installed capacity was 681.8 MW in March 2018, and the total hydropower potential is estimated at 1,284.2 MW.[3,6]

Table 1.
Small hydropower plants (up to 10 MW) in operation in Honduras

Name of the plant	*Installed capacity (MW)*	*Name of the plant*	*Installed capacity (MW)*	*Name of the plant*	*Installed capacity (MW)*
Hidro Xacbal	10.0	Rio Blanco	5.0	Matarras	1.8
Aurora	9.0	Coronado	4.5	Mangungo	1.5
Morjas	8.6	Babilonia	4.3	Rio Guineo	1.4
Cuyamel	8.0	San Carlos	4.0	Santa María del Real	1.2
Puringla Sazagua	7.4	Rio Betulia	3.6	Quilio	1.1
San Juan	6.7	Cececapa	3.5	Peña Blanca	0.9
Cortecito	6.0	Los Laureles	3.5	Agua Verde	0.8
PHP Nispero 2	6.0	San Martin	3.0	Cenit	0.8
Chacha-guala	5.4	Canjel	3.0	El Cisne	0.7
Las Glorias	5.3	Zinguizapa	2.8	Hidro Yojoa	0.5
Genera	5.2	Coyolar	2.0	Las Nieves	0.5

Source: ENEE[3]

Renewable energy policy

Aiming to reduce the share of fossil fuels in the country's energy mix, the Government approved the Incentives Law for Renewable Energy Generation in 1998. However, the law did not succeed in boosting the development of renewable energy resources. In 2007, the Law on the Promotion of Electric Power Generation from Renewable Resources was adopted. The 2007 law implemented a preferential tax policy and a preferential sales policy for natural and juridical persons developing and operating renewable energy projects. It granted additional benefits, such as tax exemptions in the forms of import duty and income tax, and introduced improvements in power purchase agreements signed with ENEE.[6,11,12] A number of later decrees approved in 2011 and 2013 further developed the regulatory framework. In particular, they:

- Created a registry of small renewable energy producers;
- Set transmission charges of 0.01 US$/kWh for renewable energy projects;
- Extended the incentives for renewable energy projects, such as exoneration of income tax, import duties and concession fees (except for hydropower), and tax credits on pre-investment expenditures;
- Extended the incentives to off-grid projects for distributed generation;
- Established net metering for users under 250 kW;
- Established a special incentive for solar PV projects, fixing the duration of the 10 per cent incentive at 15 years and adding an extra premium of 0.03 US$/kWh, that had started operations before August 2015, 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 providing a structure of the electricity sector based on a ratio of 60 per cent renewable energy and 40 per cent fossil fuel, in compliance with the provisions of the Country Vision and National Plan Law constituted into State Policy by Decree No. 286-2009. This target was set for 2022 but has already been achieved.[6,14] The Government recognizes the potential of indigenous renewable energy to improve industrial, commercial and residential access to a reliable and affordable grid-connected power, in particular in rural areas. Currently, the Government's priorities are to scale-up the access to electricity services in rural areas and to promote rural access to clean energy cooking solutions.[6]

The Honduras Scaling-Up Renewable Energy Programme in Low-Income Countries (SREP) is providing US$ 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.[6,15]

Legislation on small hydropower

Following the energy crisis of 1994, the Government of Honduras negotiated with the European Commission (EC) in order to promote electricity generation from renewable energy sources and to encourage energy conservation. In January 1996, a financing agreement was established between the EC and ENEE. After an initial two-year project, the EC donated EUR 250,000 (US$ 283,000) to create the Hydroelectric Pre-Investment Fund, which provides loans to the private sector. Since 1999, this ENEE pre-investment fund has helped finance feasibility studies for SHP projects of installed capacity up to 5 MW.[6,14]

Barriers to small hydropower development

The 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;
- It is not common for domestic commercial banks to provide equity to renewable energy projects;
- The lack of ancillary services markets.
- The need to invest in a transmission network.[6,16,17]

References

1. World Bank (2017). *Population, total*. Available from http://data.worldbank.org
2. United Nations Food and Agriculture Organization (FAO) (2015). *Honduras*. Aquastat database. Available from www.fao.org/nr/water/aquastat/countries_regions
3. National Company of Electric Energy (ENEE) (2018). *Boletín Estadístico. Marzo 2018.* Available from http://www.enee.hn/planificacion/2018/boletines/Boletin%20Estadistico%20Marzo%202018.pdf
4. World Bank (2016). *Access to electricity (% of population)*. Available from https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS
5. The International Journal on Hydropower & Dams (IJHD) (2015). *World Atlas & Industry Guide, 2015*. Aqua-Media International, Wallington, UK. Available from www.hydropower-dams.com
6. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
7. Honduras, Ley General de la Industria Electrica, (2014). Available from http://www.enee.hn/noticias/LEY%20GENERAL%20DE%20LA%20INDUSTRIA%20EL%c9CTRICA%2004%2%20DEJULIO.pdf
8. Honduras Energy Company (EEH) (n.d.). *Tarifas de Energía.* Available from https://www.eeh.hn/es/tarifas-de-energia-PG55
9. Climate Investment Fund (CIF) (2011). *Programme on Scaling-Up Renewable Energy in Low-Income Countries (SREP) Agenda Item 6: Investment Plan for Honduras*. Paper presented at Meeting of the SREP Sub-Committee. Washington D.C., 1 November 2011
10. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
11. Honduras, Decreto No.70-2007, Ley de Promocion a la Generacion deEnergia Electrica Con Recursos Renovales. *La Gaceta*, 2 October 2007. Available from www.tsc.gob.hn/leyes/Ley%20de%20Promocion%20a%20la%20Generacion%20de%20Ener-

gia%20Electrica%20con%20Recursos%20Renovables.pdf

12. Flores, W. (2012). *Analysis of regulatory framework of electric power market in Honduras: Promising and essential changes.* Utilities Policy 20 (2012), pp 46-51
13. International Energy Agency (IEA) (n.d.). *Law on the Promotion of Electric Power Generation with Renewable Resources (Ley de Promoción para la Generación de Energía Eléctrica con Recursos Renovables).* Available from https://www.iea.org/policiesandmeasures/pams/honduras/name-161266-en.php?s=dHlwZT1yZSZzdGF0dXM9T2s,&return=PG5hdiBpZD0iYnJlYWRjcnVtYiI-PGEgaHJlZj0iLyI-SG9tZTwvYT4gJnJhcXVvOyA8YSBocmVmPSIvcG9saWNpZXNhbmRtZWFzdXJlcy8iPlBvbGljaWVzIGFuZCBNZWFzdXJlczwvYT4gJnJhcXVvOyA8YSBocmVmPSIvcG9saWNpZXNhbmRtZWFzdXJlcy9yZW5ld2FibGVlbmVyZ3kvIj5SZW5ld2FibGUgRW5lcmd5PC9hPjwvbmF2Pg,,
14. Rivera, F. and Ángel, M. (2011). *Marco Legal de Energía Renovable en Honduras y Perspectivas de Desarrollo*. Presentation to the XV Reunión Anual Iberoamericana de Reguladores de la Energía. Santo Domingo, 6-8 April. Available from www.naruc.org/international/Documents/HONDURAS%20-%20Figueroa%20SPANISH%20rev.pdf
15. Climate Investment Fund (CIF) (2014). *Honduras, Country Profile*. Available from http://www.cif.climateinvestmentfunds.org/country/Honduras
16. Asociacion Hondurena de Productores de Energia Renovable (2015). *Sub-Sector Energetico Honduras.*, Oscar Enrique Kafati, Available from www.ahper.org
17. International Renewable Energy Agency (IRENA) (2018). *Accelerating Renewables Deployment in Regional Electricity Market: Honduras.* Presentation at Regional Meeting "Clean Energy Corridor of Central America (CECCA), Panama, 23 May 2018. Available from http://www.irena.org/-/media/Files/IRENA/Agency/Events/2018/May/Honduras-presentation---accelerating-renewables-in-the-regional-market---23-May.pdf?la=en&hash=-466436443454BE64C66FFB164D09AFEF55605192

2.2.6 Mexico

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

Key facts

Population	124,737,789[1]
Area	1,964,375 km^2, including 5,127 km^2 of islands[2]
Climate	There is a great diversity of climate in Mexico due to its geographical extension and relief: it is dry in most of the centre and north (28.3 per cent of the country); very dry in the north-west (20.8 per cent); warm humid in the south (4.7 per cent); warm sub-humid along the coasts (23.0 per cent); temperate humid in the mountains of the south (2.7 per cent); and temperate sub-humid in the mountains near the coasts (20.5 per cent).[3]
Topography	Mexico's main topographic features evolve from the activity of four tectonic plates. The Peninsula of Baja California is a 1,200 km long mountainous chain. The Western Sierra Madre is a mountainous chain parallel to the Pacific coast with a length of some 1,400 km, ranging in altitude from 2,000 to 3,000 metres. The Eastern Sierra Madre runs parallel but is separated by vast plains from the Gulf of Mexico over some 600 km long, ranging in altitude from 1,200 to 3,000 metres. The Sonora and Chihuahua Deserts border the United States of America in the north-west. The Central High Plateau ranges from 500 to 2,600 metres of altitude. The Neovolcanic Axis goes from the west coast to the east coast, south of Mexico City, with a peak altitude of 5,747 metres. The Southern Sierra Madre runs over 1,200 km parallel and very close to the south-western coast with a peak altitude of 3,850 metres. The Sierra Madre of Oaxaca in the southeast is some 300 km long, with peaks of about 3,000 metres. The Peninsula of Yucatan in the far south-east is a relatively flat *karst* formation with almost no streams or rivers.[4,5]
Rainfall pattern	From 1971 to 2000, the average precipitation for the country was 760 mm per year. The spatial distribution varies greatly, from 100 mm in the north-west to 2,350 mm in the south-east. Every year, between July and October, there are tropical storms and hurricanes that reach both littorals. From 1970 to 2012 there were 200 such events, most of them on the Pacific coast, but the strongest occurred on the Atlantic coast. The rainy season, from May to October, accumulates 83 per cent of the annual rainfall.[6]
Hydrology	The country is divided into 37 hydrologic regions, which are further divided into 158 river basins and 976 sub-basins. The total mean runoff is estimated in 379,000 hm^3 per year, equivalent to 193 mm/year across the entire country, or 25 per cent of its annual rainfall. The five hydrologic regions with the largest runoff are in the South-East: Grijalva-Usumacinta (shared with Guatemala), Pánuco, Papaloapan, Costa Chica de Guerrero and Coatzacoalcos. The five hydrologic regions with the largest geographical extension but with less pluviosity than the previous group are: Bravo (shared with the United States of America), Sonora Sur, Lerma-Santiago, Balsas and Sinaloa.[7,8]

Electricity sector overview

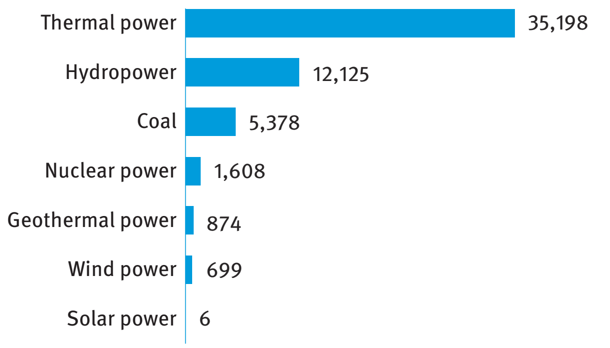
As of May 2017, Mexico's total effective capacity was 55,889 MW, distributed by sources as shown in Figure 1.[9] There are now 16 plants under construction with a combined capacity of 10,988 MW, which will start operation between 2018 and 2020; 13 of them are thermal, two are geothermal and one is a hydropower plant of 240 MW.

The total electricity generation in 2016 was 263,393 GWh (Figure 2).[10] The overall energy mix in 2016 was 81.7 per cent from fossil fuels (including thermal and coal), 4.0 per cent from nuclear and 14.3 per cent of renewable energy sources, including solar, wind, geothermal and hydropower.[10] The Law of Energy Transition considers nuclear generation, efficient cogeneration and carbon sequestration as clean energy. Thus, the clean energy portion in the energy mix in 2016 amounted to 18.3 per cent of the total.

The national electrification rate at the end of 2017 was 98.6 per cent, ranging from 99.7 per cent in the state of Colima, to 96.2 per cent in Guerrero.[11] At the end of 2016, there were around 1.8 million inhabitants without access to electricity in rural communities, mainly due to their dispersion in mountainous areas, which represents almost 1.5 per cent of the total population. Part of them could be served by renewable energy and micro-hydropower in particular.[1]

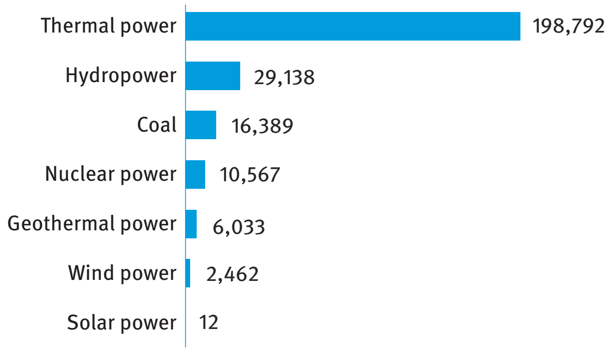
In December 1992 the then existing Law of the Public Service of Electric Energy (LSPEE) was amended to allow private participation in the generation of electricity, including self-supply, cogeneration, external production, small producers, importing and exporting. The use of transmission networks was also permitted with a simplified low-price scheme. Previously, private energy generators were not permitted by law to sell their production to the public, but could exclusively use it for self-supply, to sell it to the Federal Commission of Electricity (CFE) or to export. Private generators were allowed to form a project-specific enterprise, including as partners in a pool of industrial, commercial and municipal end-users. These new enterprises were considered to fulfil the condition of self-supply.

Figure 1.
Installed electricity capacity by source in Mexico (MW)



Source: SENER[9]

Figure 2.
Annual electricity generation by source in Mexico (GWh)



Source: SENER[10]

There are 30 power plants belonging to external producers that entered into operation in or after 2000, with 13,247 MW installed capacity; 24 combined cycle plants in different states and six wind power plants in the state of Oaxaca.[12]

In 2013, a large process of radical reforms of the legal and institutional framework of the energy sector was initiated, mainly focusing on the oil and gas industry but also including the electric industry. On 20 December 2013, Articles 25, 27 and 28 of the Constitution were amended. Previously, the right to generate, transmit, transform, distribute and supply electric energy for public service was only available to the public. After this constitutional change, the Government remains responsible for the planning and control of the national electricity system, as well as for the public service of the transmission and distribution of electricity. However, now private companies are also allowed to participate in the rest of the activities of the electricity industry.

Following the constitutional reform, 12 national laws were amended and nine others were established. The changes entered in force on 11 August 2014. The corresponding bylaws are being adjusted or promoted.[13] The roles of the main public institutions of the electricity sector were adjusted accordingly, including: the Secretariat of Energy (SENER), the Federal Commission of Electricity (CFE), the Regulatory Commission of Energy (CRE), the National Centre of Energy Control (CENACE), the Secretariat of Environment and Natural Resources (SEMARNAT), the National Water Commission (Conagua) and the National Commission for the Efficient Use of Energy (CONUEE).

As a consequence of the energy reform:
- CFE and PEMEX, the national oil and gas company, are now state-owned productive enterprises required to compete with private companies;
- CFE was restructured in 2016, and, as a result, nine subsidiary enterprises and four affiliated enterprises were separated from the core institution. The generation capacity of CFE was split among six subsidiaries that compete with each other with mixed energy sources and one business unit for nuclear power;
- CFE and PEMEX are allowed to form public-private associations;
- Private companies can generate and sell energy, capacity and associated products, except for nuclear generation and its supply to domestic users;
- Since January 2016, there is now a Wholesale Electricity Market (MEM) supervised by CENACE;
- Clean Energy Certificates (CEL) are being issued and traded since 2018;
- A spot market was created for short-term transactions. The hourly Marginal Local Prices of Energy (PML), calculated on 101 nodes of the national interconnected system (SIN), showed an average of 80.3 US$/MWh on 29 March 2018;[14]
- There have been three energy, capacity and CEL auctions in 2016 and 2017, with long-term contracts of 15 years awarded, predominantly to solar and wind projects. The resulting average prices have decreased from 41.80 US$/MWh to 33.47 US$/MWh to a very low price of 20.57 US$/MWh. A fourth auction was called in 2018 but later cancelled in 2019;
- Qualified users of energy, with demands of 1 MW or more, are able to buy from the MEM, energy vendors or directly from generators;
- A new type of actor, energy vendors companies, are able to intermediate in the market;
- Energy vendors and qualified users must buy a minimum percentage of capacity, either firm or interruptible;
- There is an increasing minimum proportion of clean ener-

gy for participants in MEM transactions, set to 5 per cent in 2018, 7.4 per cent in 2020, 10.9 per cent in 2021 and 13.9 per cent in 2022;[15]

- Private companies are allowed to participate in the expansion and operation of the transmission and distribution networks;
- The price scheme for the electric transmission service has been changed to reduce subsidies.

The SEN is organized in nine regions. Seven of them form the National Interconnected System (SIN), covering most of the territory with dense electric transmission and distribution networks. The peninsula of Baja California has two regional networks. There are capacity restrictions in some nodes of the SIN that impose limitations or delays to the addition of new plants.

Since there is a margin of operating reserve, the shortage of electricity on a regional or seasonal scale normally does not occur. However, some outages of electric supply of short duration and limited extension may occur. The average annual interruption time per user in 2014 was 36.7 minutes.[16]

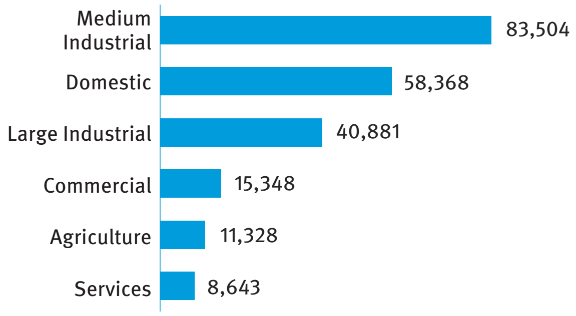
A transmission line of 103 km at 400 kV linking Mexico and Guatemala started operation on 22 April 2010. It had an initial capacity of 200 MW towards Guatemala and 70 MW in the opposite direction.[17] There are plans to connect this strategic link to the SIEPAC transmission system, traversing 1,800 km at 230 kV with a capacity of 600 MW, which serves six countries of the Regional Electric Market of Central America.[18] In addition, Mexico is connected to Belize by a transmission line with a capacity of 65 MW. To the North, Mexico has 11 interconnections with the States of Texas and California in the USA, with capacities ranging from 36 MW to 800 MW.

The total gross demand of capacity in 2018 was estimated at 46,349 MW. With the expected annual rate of growth in 2013-2028 of 4.0 per cent, it could reach 70,591 MW in 2028. Thus, some 24,242 MW of additional capacity will be needed in the next 10 years, 52.3 per cent more than the present, considering a margin of reserve. The total gross demand of energy in 2018 was estimated at 298,948 GWh; including sales by CFE, remote self-supply, exports, energy savings, reduction of energy losses and CFE internal consumption. With the expected annual rate of growth in 2013-2028 of 3.8 per cent, it could reach 472,453 GWh in 2028. Thus, some 173,505 GWh of additional energy will be needed in 10 years, 58.0 per cent more than the present.[19]

The total internal energy sales of CFE in 2016 were 218,072 GWh, distributed by user category as shown in Figure 3.[20]

In 2016, aggregated internal energy sales were highest in August, with 20,368 GWh, and lowest in January, with 15,719 GWh. In 2015, the total exports of energy were 2,320 GWh, 73.4 per cent to the USA and the rest to Guatemala and Belize. The total imports of energy in 2015 were 1,650 GWh, 98.8 per cent from the USA and the rest from Guatemala.[21] Prices of energy in the neighbouring countries are higher than in Mexico, mainly in Central America, where there are countries that suffer shortages.

Figure 3.
Energy sales by user category (GWh)

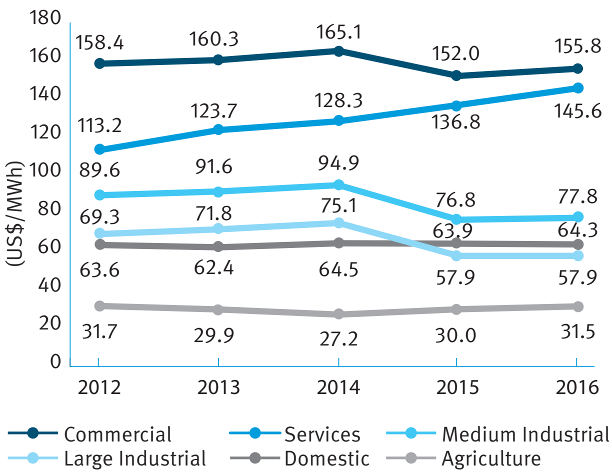


Source: SENER[20]

CFE strategic vision incorporates firstly the reduction of generation costs, mainly by decreasing the proportion of fuel oil plants in favour of natural gas and renewable energy plants, and, secondly, the reduction of energy losses. Total losses in 2016 were estimated at 12 per cent. Thirdly, CFE aims to reduce the electricity tariffs.

Figure 4 shows the tariffs annual series for six user categories from 2012 to 2016.[22] As can be seen in Figure 4, the tariffs for industrial and commercial users declined by the end of 2014.[32]

Figure 4.
Electricity tariffs by category (US$/MWh)



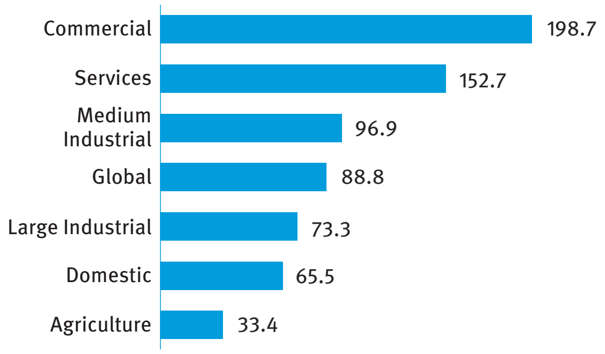
Source: SENER [22]

Note: The exchange rate considered was 18.383 MXN/US$ on 27 March 2018.

CFE has an electricity tariff structure that considers: the level of tension, the category of use, the region, the season, the required and used demand, the required continuity, the type of energy (base, intermediate and peak), the day of the week and the level and hour of consumption. This gives birth to more than 40 tariffs. In general, the highest prices are those of the Baja California and Baja California Sur regions. The lowest prices are those of the North Central, Northeast and Northwest regions. The electricity tariffs are charged in Mexican Pesos (MXN) and they are monthly indexed.

The mean tariff in May 2017 was 88.8 US$/MWh (Figure 5). The tariffs of CFE have been used as a reference in the negotiation of power purchase agreements.

Figure 5.
Annual electricity standard tariffs by user category in 2017 (US$/MWh)



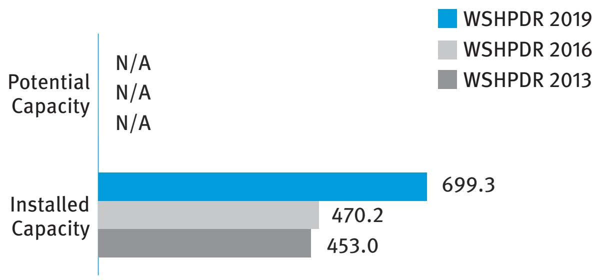
Source: SENER[22]

Note: The exchange rate considered was 18.383 MXN/US$ on 27 March 2018.

Small hydropower sector overview

A hydroelectric generation facility is considered eligible for incentives aimed at promoting clean energy projects when its capacity is lower than 30 MW; or when it has a power density of at least 10 W/m^2, which is the ratio of installed capacity to reservoir surface.[27] This can be considered as the definition of small hydropower (SHP) in Mexico. In 2015 the installed SHP capacity was 699.3 MW (Figure 6).

Figure 6.
Small hydropower capacities 2013/2016/2019 in Mexico (MW)



Source: SENER,[20] *WSHPDR 2013*,[33] *WSHPDR 2016*[32]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019.*

There has never been a nationwide study of the SHP potential and its value remains unknown. CFE has conducted planning studies in the majority of river basins looking for specific sites with an expected production greater than 40 GWh/year for several decades. In 2012, its inventory included 585 such sites, including 73 plants now in operation. The combined capacity of the remaining 512 sites was estimated at 41,132 MW, with a generation of 114,754 GWh/year, and an average plant factor of 32 per cent.[24]

In 1995, CONAE published a national estimate close to 3,250 MW for the SHP potential of Mexico, considering plants with a capacity from 2 to 10 MW.[25] It was based on an inference from data of 18 countries. Later on, the author stressed the urgent need to conduct a real assessment of the national SHP potential.[26] Nevertheless, many official and academic documents continued until present to cite the figure of 3,250 MW as a fact. There have been several official assessments of the SHP potential in natural streams of some river basins that 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 precision spectrum, there is a pioneering study requested by CONAE in 1995 of six watersheds on the Gulf of Mexico coast, covering 26,376 km^2 where a total of 100 SHP sites were identified using simplified techniques and data.[21] At the high end of the precision spectrum, there are studies requested by CFE in 2007 for three watersheds, covering 29,259 km^2, where a total of 3,118 micro-, mini- and SHP sites were identified, including 110 SHP sites, by using advanced techniques.[27]

Facing the need to estimate the SHP potential under 30 MW as input for planning purposes, SENER has published a total probable SHP potential of 2,629 MW.[28] This value is the combined capacity of 469 sites picked from the 512 in the inventory of CFE, after raising the plant factor to 100 per cent and reducing the height of the dams. This estimate is largely uncertain. Taking into account the rugged relief and heavy rainfall patterns in the vast 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 SHP potential is carried out, thousands of feasible sites will be identified instead of hundreds and that the total potential capacity will be considerably larger than what was estimated until now.

CRE has issued 112 SHP generation permits with up to 30 MW of capacity;[29] 43 of those are being developed and 69 are in operation. The combined capacity is 1,229.2 MW. The total capacity of 32 SHP plants in operation belonging to CFE is 302.07 MW. The total capacity of the 37 SHP plants in operation belonging to private owners is 397.23 MW.

The remarkable increase in SHP installed capacity when comparing the *WSHPDR 2016* and *WSHPDR* 2019 is due to the large number of generation permits issued just prior to the Energy Reform in 2013 to developers willing to benefit from the previous regulatory framework. Now, developers are facing uncertainty regarding some provisions of the new institutional and regulatory framework.

Convention No. 169 of the International Labour Organization (ILO), ratified by Mexico in 1991, sets the obligation to obtain on good faith a free, prior and informed consent from the indigenous and tribal peoples about new projects in their territory. The Law of the Electric Industry reinforces this in Art. 119. This obligation is prone to misuse by systemic opponents to hydropower projects, trying to get involved in the consultations and to manipulate the inhabitants of distant communities.

Renewable energy policy

The National Strategy for Energy Transition and the Sustainable Use of Energy sets objectives, lines of action and goals for 2024 for the Federal Government in order to promote the greater use of renewable energy and clean technologies. From 1992 until the Energy Reform there were a number of incentives for renewable energy, including the following:

- Zero import duty for equipment that prevents pollution and for research and technological development;
- Accelerated assets depreciation for infrastructure projects that use renewable energy sources;
- Contract of interconnection for intermittent renewable energy sources with favourable provisions.

In 2008, the Law for the Use of Renewable Energies and the Financing of the Energy Sector Transition (LAFERTE) was issued, which included economic, financial, fiscal, administrative, electric connection and technological incentives for renewable energy projects.[30] Likewise, in 2008, the Law for the Sustainable Use of Energy (LASE) was issued. This law also created the National Programme for Sustainable Energy (PRONASE) and the National Commission for the Efficient Energy Use (CONUEE). SENER is legally bound to assess, update and publish the national inventory of the potential of clean energy sources.

The Law of Energy Transition (LTE), which entered in force on 24 December 2015 to promote clean energy in the context of the Energy Reform, replaces the two previously mentioned laws, LAERFTE and LASE.[31] Among the main contents of LTE are the following:

- Set the goal for the clean energy portion in the generation matrix to be 25 per cent in 2018, 30 per cent in 2021 and 35 per cent in 2024;
- Provide instruments for the distributed generation and sale of energy by any person or enterprise;
- Provide for the strengthening and expansion of the transmission and distribution networks through the Programme of Smart Electric Grids;
- Strengthen the institutions responsible for promoting energy efficiency;
- Create the National Programme of Sustainable Management of Energy to achieve the energy efficiency goals.

SENER and the National Council of Science and Technology (CONACYT) have allocated funds to several Energy Innovation Centres (CEMIE) focused on wind, solar, geothermal, biomass and ocean renewable energy sources. It has not been the same for hydropower. The General Climate Change Law (LCC) has set the indicative goal of reducing CO_2 equivalent emissions by 30 per cent in 2020 and by 50 per cent in 2050, compared to baseline emissions in 2000. On 27 March 2015 Mexico presented before the United Nations Framework Convention on Climate Change (UNFCC) its goals and commitments to reduce greenhouse gas emissions (GHG) by 22 per cent by 2030 with respect to the baseline levels in 2013.

The Government's plan for the next six years, following the presidential election on 1 July 2018, aims to increase the generation by the existing hydroelectric plants and to build new plants. This is intended in order to reduce the use of natural gas and to promote the reduction of domestic electricity tariffs and preferential zones. The generation of this clean energy will be done alongside taking care of ecosystems and communities.[34]

Barriers to small hydropower development

Current barriers include the following:

- Public support for the renewable energy sector: policy makers prefer the oil and gas industry over renewable energy sources, and among renewable energy sources, solar and wind are prioritized over SHP;
- Technology: lack of a reliable national hydropower potential inventory; hydrological uncertainty due to the use of simplified hydrological methods; the non-existence of prospective studies of water resources scenarios by watersheds to assess the long-term the potential impact of hydrological changes on SHP projects; technical deficiencies in SHP project formulation due to rudimentary methods applied in the early phases of prospection and pre-feasibility studies resulting in a low success rate; inadequate technical documentation of SHP projects that adds difficulties and delays to the promotion phase; and lack of local manufacturers of turbines;
- Social: social and community concerns about hydropower projects, often based on lack of education and objective information; ideological and political opposition induced against hydropower projects, private participation and foreign investments; disproportionate expectations of local communities regarding compensation to remedy regional underdevelopment and lack of services; delays or blockage of projects caused by environmental and social opposition; regional insecurity and delinquency;
- Regulatory: requirements for elaborate, extensive and costly feasibility studies prior to having the assurance of obtaining all required permits for the project; complex and multiple licensing procedures with federal, state and municipal authorities due to lack of a one-stop/single window scheme; restrictions to issue water-use permits for generation in river basins with extraction regulation or bans, even if hydropower is non-consumptive; high restrictions on projects proposed in protected areas, without objective balance of positive and negative impacts; difficulty in licensing SHP projects in existing hydraulic urban and irrigation infrastructure; requirement to connect to the electric grid in higher tensions; exposure to risk of issuance of new concessions for different water uses or diversions upstream of the hydropower project; delays in the consultation to obtain the consent of indigenous populations due to lack of personnel and funding in the involved public institutions; period from one to three years for licensing processes;
- Legal: exposure to the risk of legal project interruption due to social or environmental pressures; risk of legal challeng-

es by another developer for a site that is under prospection or licensing process; long period of contract preparation for structuring projects;

- Economic: lack of coverage and maintenance of the roads in areas with high hydropower potential, requiring major investments in access roads; lack of coverage and capacity of the electric grid in some areas with high hydropower potential, requiring major investments in interconnection lines; generation and transmission electric networks that have privileged concentrated generation over distributed generation; charges or duties for the volume of water used to generate energy, rather than for the energy produced; inadequate or incomplete costs-benefit assessments of SHP project flows ; difficulty of valuation of positive externalities of renewable energy sources;
- Commercial: low credit rating of prospective energy consumers; low price of the energy delivered to the national electric system; exposure to the risk of decline in energy prices due to energy auctions; difficulty to access mechanisms of payment for greenhouse gas emissions reduction;
- Financial: lack of financing options for the prospection and pre-feasibility phases; limitation of funds made available by the commercial banks in the country for SHP projects; terms of commercial credit that are not conducive; requirement to augment the ratio of equity capital to debt; difficulty to access equity capital for some developers; requirement to structure syndicated loans for larger projects; high requirements of banks to assess the specific track record and financial solvency of the project developers; high requirements of financial guarantees beyond a project's expected cash flow (including long-term power delivery agreements, high credit rating of energy consumer partners, construction and supervision contracts with highly ranked and costly firms), preparation and maintenance contracts during the loan term; and requirement of obtaining the opinions from independent experts.[32]

References

1. Proyecciones de Población 2010-2050. *SEGOB/CONAPO*. www.conapo.gob.mx/es/CONAPO/Proyecciones (accessed April 11, 2018)
2. Referencias geográficas y extensión territorial de México. *INEGI*. www.inegi.org.mx/inegi/SPC/doc/internet/1-GeografiaDeMexico/MAN_REFGEOG_EXTTERR_VS_ENERO_30_2088.pdf (accessed April 11, 2018)
3. Prieto, Gonzalo/SMN (2015). Clima de México*. Conagua/SMN*. https://www.geografiainfinita.com/2015/07/el-clima-de-mexico-a-traves-de-los-mapas/ (accessed April 11, 2018)
4. Fernández López, Justo (2015). *Geografía y relieve de México*, HISPANOTECA (adapted). http://hispanoteca.eu/Landeskunde-LA/Geograf%C3%ADa%20y%20relieve%20de%20M%C3%A9xico.htm (accessed April 11, 2018)
5. Lugo-Hubp, José (1990). *El relieve de la República Mexicana*. http://satori.geociencias.unam.mx/9-1/(7)Lugo.pdf (accessed April 11, 2018)
6. Comisión Nacional del Agua (2016). *Atlas del Agua en* México 2016. http://201.116.60.25/publicaciones/AAM_2016.pdf (accessed April 11, 2018)
7. Istituto National de Estadistica y Geografia (INEG) (nd). *Red Hidrográfica escala 1:50 000 edición 2.0*. http://www.inegi.org.mx/geo/contenidos/topografia/regiones_hidrograficas.aspx (accessed April 11, 2018)
8. Conagua (2016). Estadísticas del Agua en México**,** edición 2016. https://agua.org.mx/wp-content/uploads/2017/03/Estadisticas-del-Agua-en-Mexico_2016.pdf (accessed April 11, 2018)
9. Sector Eléctrico Nacional. Capacidad efectiva de generació (2015a). *SENER*. http://egob2.energia.gob.mx/portal/electricidad.html (accessed April 11, 2018)
10. SENER (2015b). *Sector Eléctrico Nacional. Generación Bruta*. http://egob2.energia.gob.mx/portal/electricidad.html (accessed April 11, 2018)
11. CFE (2015b). *Electrificación por entidad federativa*. https://datos.gob.mx/busca/dataset/electrificacion-por-entidad-federativa (accessed April 11, 2018)
12. CFE (2015c). *Datos técnicos de los Productores Externos de Energía en Operación*. http://egob2.energia.gob.mx/portal/electricidad.html (accessed April 11, 2018)
13. Presidencia de México*. Iniciativas de Leyes Secundaias*. http://presidencia.gob.mx/reformaenergetica/#!leyes-secundarias (accessed April 11, 2018)
14. CENACE (2018). *Historia de Precios de Energía de Nodos Distribuidos*. http://www.cenace.gob.mx/SIM/VISTA/REPORTES/H_RepPreEnergiaSisMEM.aspx?N=29&opc=divCssPreEnergia&site=Precios%20de%20la%20energ%C3%ADa/Precios%20de%20Nodos%20Distribuidos/MTR/Diarios&tipoArch=C&tipoUni=SIN&tipo=Diarios&nombrenodop=Precios%20de%20Nodos%20Distribuidos (accessed April 11, 2018)
15. SENER (2017). *Aviso en DOF*: 31/03/2017. http://www.dof.gob.mx/nota_detalle.php?codigo=5478190&fecha=31/03/2017 (accessed April 11, 2018)
16. CFE (2015d). *Tiempo de interrupción por usuario*. http://www.cfe.gob.mx/ConoceCFE/1_AcercadeCFE/Estadisticas/Paginas/Indicadores-operativos.aspx (accessed April 11, 2018)
17. CFE (2013). *Interconexión Eléctrica* México-Guatemala. Presentation by Roberto Duque Ruiz at the Mexico Energy Summit, on March 7, 2013.
18. CFE (2016). *Informe Anual 2015*.https://www.cfe.mx/inversionistas/Documents/informe_anual/Informe-Anual-2015-CFE-Acc.pdf (accessed April 11, 2018)
19. CFE (2013). *Programa de Obras e Inversiones del Sector Eléctrico POISE 2014-2018*. http://www.amdee.org/Publicaciones/POISE-2014-2028.pdf (accessed April 11, 2018)
20. SENER (2015c). *Sector Eléctrico Nacional. Ventas Internas de Energía Eléctrica*. http://egob2.energia.gob.mx/portal/electricidad.html (accessed April 11, 2018)
21. SENER (2017). *Comercio Exterior de Energía Eléctrica*. https://datos.gob.mx/busca/dataset/comercio-exterior-importacion-y-exportacion-de-energia-electrica (accessed April 11, 2018)
22. SENER (2018). *Sector Eléctrico Nacional. Precios medios de Energía Eléctrica*. hhttp://egob2.energia.gob.mx/portal/electricidad.html (accessed April 11, 2018)
24. Marengo M., Humberto (2012). *Proyectos Hidroeléctricos - Sustentabilidad*. Ponencia en V Congreso Nacional de la Academia de Ingeniería, Usos del agua. México, D. F., February, 2012.
25. Conae (1995). *Situación actual de la minihidráulica y determinación del potencial aprovechable en una región de los estados de Veracruz y Puebla*. Valdez Ingenieros, S. A. de C. V., México, D.F., 1995.

26. Valdez B., Luis H., SENER (2005). *Anexo 8 Estimación del Recurso para Pequeña, Mini y Micro Hidroenergía: Aplicaciones en* México, p. 12. Valdez Ingenieros S.A. de C.V. Cuernavaca, Morelos, August 19, 2005. https://es.scribd.com/document/248090092/GUIA-MINICENTRALES (accessed April 11, 2018)
27. Trelles, A. (2009). *Evaluation of small hydropower potential in three river basins of Mexico*. Presented at the Small Hydro 2009 Conference. April 29-29, 2009, Vancouver, B.C. Canada. http://kchydro.nfshost.com/International/Day1_Ing_Armando_Trelles.pdf (accessed April 11, 2018)
28. SENER (2014). *Inventario Nacional de Energías Renovables (INERE)*. Portal interactivo. https://dgel.energia.gob.mx/inere/ (accessed April 11, 2018)
29. CRE (2018). *Permisos Vigentes de Generación Eléctrica por Tipo de Energético Primario Utilizado*. https://datos.gob.mx/busca/dataset/permisos-vigentes-de-generacion-electrica-por-tipo-de-energetico-primario-utilizado (accessed April 11, 2018)
30. Cámara de Diputados (2013). *Ley para el aprovechamiento de energías renovables y el financiamiento de la transición energética*. http://www.senado.gob.mx/comisiones/energia/docs/marco_LAERFTE.pdf (accessed April 11, 2018)
31. Cámara de Diputados (2015). *Ley de transición energética*. http://www.diputados.gob.mx/LeyesBiblio/pdf/LTE.pdf (accessed April 11, 2018)
32. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org. (accessed April 23, 2018)
33. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
34. López Obrador, A. (2018). *Proyecto de Nación 2018-2024*. https://drive.google.com/file/d/16i4blJ_Yp1eCHvoeUed3SUWCvH1Ss2dF/view (accessed July 29, 2018)

2.2.7 Nicaragua

Jaime Muñoz, Asofenix Nicaragua; and International Center on Small Hydro Power (ICSHP)

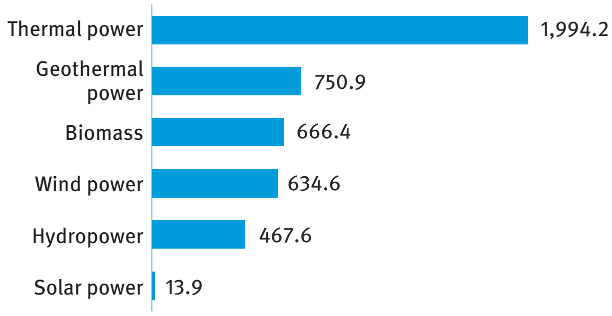
Key facts

Population	6,217,581[1]
Area	130,370 km^2 [1]
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 rainy season lasts for nine months, while the dry season is from March to May. Annual temperatures across the country average 27 °C. However, in the northern mountains the climate is cooler with average temperatures of 18 °C.[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 mountains. 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 km in width.[2]
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	Nicaragua's central mountains form the main watershed. The rivers flowing to the west of it are short and drain into the Pacific Ocean or Lakes Managua and Nicaragua. The most important rivers in this part of the country are the Negro, Estero Real and Tamarindo rivers. 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). In the west lies the region of lakes, with Lake Nicaragua being the largest lake in Central America.[2]

Electricity sector overview

In 2017, electricity generation in Nicaragua was approximately 4,527 GWh, of which thermal power accounted for 44 per cent, geothermal power for almost 17 per cent, biomass for almost 15 per cent, wind power for 14 per cent, hydropower for 10 per cent and solar power for only 0.3 per cent (Figure 1).[3] An additional 327 GWh of electricity was imported, while 1 GWh was exported.[4]

Figure 1.
Electricity generation by source in Nicaragua (GWh)

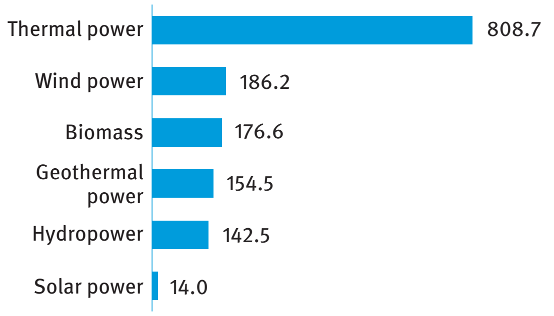


Source: INE [3]

As of July 2018, the total installed capacity of Nicaragua was approximately 1,482 MW. Thermal power accounted for almost 55 per cent of the total installed capacity, wind power for 13 per cent, biomass for 12 per cent, geothermal power and hydropower for approximately 10 per cent each and solar power for less than 1 per cent (Figure 2).[5] 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. However, the available capacity of the country's electricity system was lower at 1,136 MW.[5] Compared to 2017, the installed capacity remained unchanged, whereas the available capacity decreased by some 26 MW.[6]

In the late 1990s, the electricity sector of Nicaragua underwent a restructuring, whereby the state-owned utility Empresa Nicaraguensa de Electricidad (ENEL) was unbundled and its generation and distribution units were privatised. The reform resulted in the creation of four generation companies (GEMOSA, GEOSA, HIDROGESA and GECSA), one transmission company (ENTRESA) and two distribution companies (DISNORTE and DISSUR). Electricity transmission remains public and is managed by the state-owned ENTRESA, while two generation companies were privatized and the two distribution companies were sold to the Spanish company Unión Fenosa, with a concession that covers the western, central and northern parts of the country. However, the eastern part remains in the responsibility of ENEL, which manages some mini-grids on the Atlantic coast.[7,8]

Figure 2.
Installed electricity capacity by source in Nicaragua (MW)



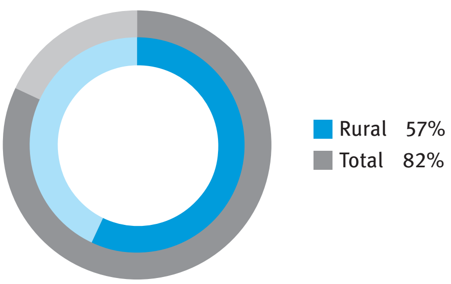
Source: INE[5]

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 (above 2 MW of installed capacity). The electricity sector is regulated by the Instituto Nicaragüense de Energía (Nicaraguan Energy Institute, INE). While the transmission and distribution are both subjected to regulated tariffs, generating companies can freely compete in the market. The Comité Nacional de Despacho de Carga (National Load Dispatch Committee, CNDC) is the electricity market operator and the Ministry of Energy and Mines (MEM) oversees energy policy and planning.[9]

In recent years, the electricity sector of Nicaragua has undergone significant changes. The Government has made efforts to improve the reliability of electricity supply and improve electricity access in vulnerable areas.[10] The overall electrification rate in Nicaragua reached 82 per cent in 2016, with 99 per cent in urban areas and 57 per cent in rural areas (Figure 3).[11]

In the first half of 2018, electricity prices averaged 0.065 NIO/kWh (0.002 US$/kWh).[12]

Figure 3.
Electrification rate in Nicaragua (%)

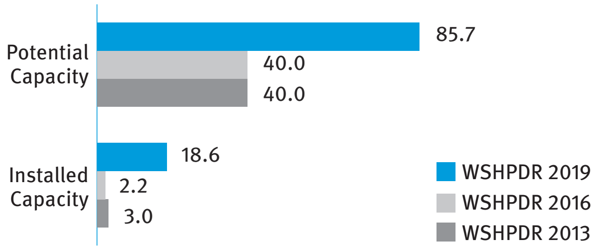


Source: World Bank[11]

Small hydropower sector overview

The definition of small hydropower (SHP) in Nicaragua is up to 10 MW. The installed capacity of SHP is 18.6 MW, while the potential is estimated to be 85.7 MW, indicating that approximately 22 per cent has been developed.[13] Compared to the *World Small Hydropower Development Report* (*WSHPDR*) *2016*, the installed capacity has increased more than seven-fold, while the potential capacity doubled (Figure 3). Such significant changes are predominantly due to access to more accurate data.

Figure 4.
Small hydropower capacities 2013/2016/2019 in Nicaragua (MW)



Source: *WSHPDR 2016*,[9] MEM,[13] *WSHPDR 2013*[14]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

As of 2017, there were 14 operational SHP plants with a combined capacity of 18.61 MW (Table 1). A further 20 potential sites with a combined capacity of 67.1 MW were identified.[13]

Table 1.
Operational small hydropower plants in Nicaragua

Name of the plant	*Installed capacity (MW)*	*Location*
El Diamante	5.00	Sanr Ramón Matagalpa
Salto Grande	2.80	Bonanza, RAAN
Las Cañas	2.70	Matagalpa, Matagalpa
Siempre Viva	2.50	Bonanza, RAAN
El Wawule	1.72	Sanr Ramón Matagalpa
El Sardinal	1.20	El Tuma La Dalia, Matagalpa
El Bote	0.96	El Cuá Jinotega
Bilampí-Musun	0.34	Río Blanco, Matagalpa
Tichana	0.33	Ometepe, Rivas
Kubalí-La Florida	0.30	Waslala, RAAN
San José Bocay (Aprodelbo)	0.26	Jinotega
Las Nubes El Naranjo	0.22	Waslala, RAAN
Rio Bravo Puerto Viejo	0.18	Waslala, RAAN
1ro de Febrero	0.10	El Tuma, Matagalpa
Total	**18.61**	

Source: MEM[13]

SHP development in Nicaragua is mainly financed by private investors or international organizations, including the European Investment Bank and the Inter-American Investment Bank. In addition, there is a robust system of local microfinance institutions that provide green finance at an average interest rate of 1.5-28 per cent.[9]

Renewable energy policy

The Government of Nicaragua aims to increase the share of renewable energy sources (hydropower, wind, solar, biomass and geothermal power) in the country's energy mix. Although there is no renewable energy policy in place, the National Energy Policy (2004) establishes the policy framework for the promotion of renewable energy.[15]

The Plan for Electricity Generation Expansion 2016-2030 foresees the addition of 1,223 MW of new capacity to the country's electricity system by 2030. 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-type hydropower and 22 MW of run-of-river hydropower capacity. However, the plan also foresees 440 MW of new thermal power capacity, including fuel oil- and natural gas-fired plants. Nonetheless, by 2030 the share of thermal power in the country's energy mix is expected to decrease from the present 44 per cent to 27 per cent and, correspondingly, the share of renewable energy is expected to increase to 73 per cent.[16]

Thus, among all renewable energy sources, hydropower will see the greatest addition of new capacity in the coming decade. 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. The necessary environmental permits are obtained from the Ministry of Environment and Natural Resources, generation licences from the Instituto Nicaragüense de Energía (INE) and water concessions from the Ministry of Development, Industry and Trade (MIFIC).[9,17]

Law 476 for the Promotion of the Hydroelectric Subsector stipulates that hydropower schemes below 1 MW do not need a water concession. Instead, producers can obtain a permit for a period of 15 years. For schemes with capacities of 1 MW to 5 MW, a simplified procedure applies for obtaining a water concession from the MIFIC. 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.[17]

In addition, according to Law 532 for the Promotion of Electric Generation from Renewable Sources, all renewable energy projects receive the following incentives:

- Full exemption from taxes on the sale of carbon bonds;
- Exemption from all taxes that might exist for the exploitation of natural resources for a maximum of five years after the start of operations;
- Exemption from payment of customs duties and value added tax (VAT) on imports, machinery, equipment and all materials intended solely for the pre-investment and construction of a sub-transmission line for the national interconnection system.[9]

Barriers to small hydropower development

The 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 projects, since the latter continue to be highly subsidized.[9]

References

1. World Bank (2017). *Nicaragua. Population, total.* Available from https://data.worldbank.org/indicator/SP.POP.TOTL?locations=NI
2. Encyclopaedia Britannica (2018). *Nicaragua.* Available from https://www.britannica.com/place/Nicaragua
3. Instituto Nicaragüense de Energía (INE) (2018). *Generación bruta, Sistema eléctrico nacional, año 2017.* Available from https://www.ine.gob.ni/DGE/estadisticas/2017/generacion_bruta_2017_actmar18.pdf
4. Instituto Nicaragüense de Energía (INE) (2018). *Importaciones y exportacioned de energía, año 2017.* Available from https://www.ine.gob.ni/DGE/estadisticas/2017/importaciones_exportaciones_2017_actmar18.pdf
5. Instituto Nicaragüense de Energía (INE) (2018). *Capacidad instalada, Jul 2018.* Available from https://www.ine.gob.ni/DGE/estadisticas/2018/capacidad_instalada_julio2018_actsept18.pdf
6. Instituto Nicaragüense de Energía (INE) (2018). *Capacidad instalada, Dic 2017.* Available from https://www.ine.gob.ni/DGE/estadisticas/2017/capacidad_instalada_2017_actmar18.pdf
7. Empresa Nicaraguensa de Electricidad (ENEL) (n.d.). *Historia Jurídica.* Available from http://www.enel.gob.ni/index.php/quienes-somos/historia-juridica-enel
8. Ministry of Energy and Mines (MEM) (2010). *Agentes productores conectados al sistema interconectado del mercado electrico nacional.* Available from http://www.mem.gob.ni
9. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016.* United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
10. SE4ALL (2013). *Rapid Assessment Gap Analysis: Nicaragua.* Available from https://www.seforall.org/sites/default/files/Nicaragua_RAGA_EN_Released.pdf

11. World Bank (2016). *Nicaragua. Access to electricity (% of population).* Available from https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=NI
12. Instituto Nicaragüense de Energía (INE) (2018). *Precio promedio de la energía eléctrica (C$/kWh), año 2018.* Available from https://www.ine.gob.ni/DGE/estadisticas/2018/precio_promedio_julio2018_actsept18.pdf
13. Ministry of Energy and Mines (MEM) (2017). Proyectos de centrales hidroeléctricas en Nicaragua. Available from http://www.mem.gob.ni/wp-content/uploads/2017/03/P-Hidro_2017WEB_75dpi.jpg
14. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013.* United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
15. President of the Republic of Nicaragua (2004). *Establicimiento de la Política Energética Nacional, Decreto No. 13-2004.* Available from http://legislacion.asamblea.gob.ni/Normaweb.nsf/%28$All%29/291F7E6A862DB72D062570A100582A64?OpenDocument
16. Ministry of Energy and Mines (MEM) (2017). *Plan de Expansion de la Generacion Electrica de 2016-2030.* Available from http://www.mem.gob.ni/wp-content/uploads/2017/03/Plan-de-Expansion-2016-2030.pdf
17. Renewable energy focus (2012). *Nicaragua powers up on green energy.* Available from http://www.renewableenergyfocus.com/view/24020/nicaragua-powers-up-on-green-energy

2.2.8 Panama

José Fábrega, Denise Delvalle and Alexis Baúles, Centro de Investigaciones Hidráulicas e Hidrotecnicas, Universidad Tecnológica de Panamá

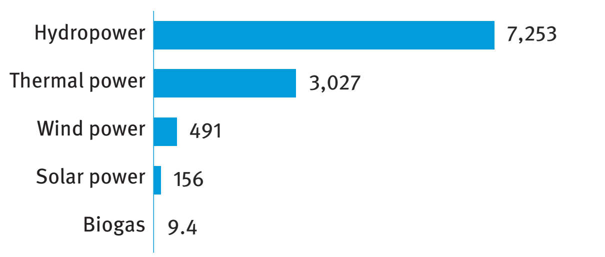
Key facts

Population	4,037,043[1]
Area	75,420 km[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 temperatures on the coast regularly reach 35 °C, however, at higher altitudes the temperatures decrease by 1 °C for every 150 metres.[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]
Rain pattern	Yearly precipitation in Panama averages approximately 3,000 mm. The Pacific region experiences a wet season from May to November, while, for the Atlantic region, precipitation is continuous throughout the year.[2,3]
Hydrology	There are approximately 500 rivers in Panama in 52 watersheds. Seventy per cent of rivers run to the Pacific side (longer streams) and 30 per cent to the Atlantic side.[4]

Electricity sector overview

The main sources of electricity generation in Panama are hydropower and thermal power. In 2017, electricity generation was at 10,936 GWh, of which 72 per cent came from renewable energy sources (Figure 1).[5]

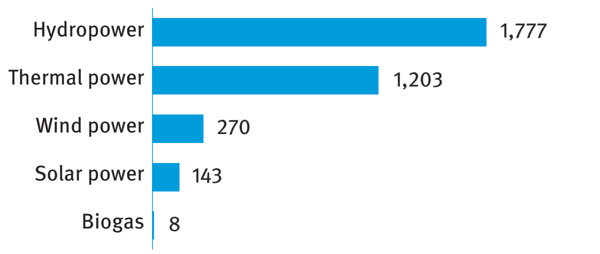
Figure 1.
Annual electricity generation by source in Panama (GWh)



Source: SNE[5]

At the end of 2017, Panama had 3,401 MW of installed electrical capacity, which was 45 per cent higher than in 2011 (2,344 MW).[5] Renewable energy sources, including hydropower, wind power, solar power and biogas, contributed 64 per cent, while thermal power accounted for 37 per cent (Figure 2). Compared to the *World Small Hydropower Development Report (WSHPDR) 2016*, the most pronounced increase has been observed in the installed capacity of wind and solar power, which have been predominantly developed under power purchase agreements (PPAs) allocated through auctions.[6]

Figure 2.
Installed electricity capacity by source in Panama (MW)



Source: SNE[5]

A significant role in the electricity sector of Panama is played by the Panama Canal Authority, which is the biggest independent electricity producer in the country, with an installed capacity of 220.7 MW (73 per cent from thermal power and 27 per cent from hydropower).[8]

The National Secretariat of Energy (Secretaria Nacional de Energía, SNE), established by Law No. 43 on 23 April 2011, is in charge of the energy sector.[9] The Rural Electrification Office (Oficina de Electrification Rural, OER) is responsible for providing energy to the rural, isolated areas that are not connected to the national grid. The OER has a target to increase the electrification rate in rural areas using photovoltaic solar power and electricity grids for short distances (10 km). From November 2013 to October 2014, up to 109 projects were completed in the provinces of Colon, Darien, Coclé, Bocas del

Toro and in indigenous territories. As a result, approximately 25,000 inhabitants received access to electricity.[10] In 2016, 94 per cent of the population had access to electricity, including 99 per cent in urban areas and 81 per cent in rural areas.[24] The OER is supervised and funded by the Ministry of the Presidency. However, all project ideas have to be proposed by the rural communities in order to be included in official planning.[2]

The energy sector is regulated by Law No. 6 of 3 February 1997 (and its later amendments) as well as by Decree Law No. 22 (1998).[9,11,12,13] After the privatization of the public electricity sector in 1998, the Empresa de Transmision Electrica S.A (ETESA) took charge of dispatching and transporting electricity in an efficient, safe and reliable way, as well as of ensuring adequate planning for the expansion of generation capacities, the construction of new facilities and the reinforcement of the transmission grid. The remuneration for the services provided by ETESA is also regulated by Law No. 6 (1997).[11]

Currently, the electricity grid of Panama consists of three main transmission lines. The Government adopted a plan to modernize and expand the transmission systems between 2014 and 2017, which was financed by the Latin American Development Bank. The plan mainly referred to the third transmission line (completed in 2017) and was replaced with the Plan for the Panama National Grid Expansion 2017-2031.[16] The current plan consists of three major components: i) basic studies, including the forecast of energy demand and power at the level of the Main Transmission System; ii) the "Indicative Generation Plan", outlining the plans to increase generation, providing information on the evolution of the generation sector, describing the current supply situation and defining the potential alternatives to meet the demand; and iii) the "Transmission System Expansion Plan", compliance with which will be mandatory once it has been approved by the National Authority of Public Services (Autoridad Nacional de los Servicios Públicos, ASEP).[14]

The total electricity consumption considering all sectors (private, commercial, governmental, industrial and public electrification facilities) in Panama in 2016 was 8,588 GWh.[26] Thus, per capita consumption in 2016 was 2,127 kWh, which is almost twice as high as the average consumption rate in Central America (1,170 kWh per person).[15] According to the National Energy Plan update (2017), the total installed capacity and electricity generation of Panama should increase to 4,746 MW and 16,098 GWh, respectively, by 2030.[26]

Panama is exporting its electricity surplus to neighbouring countries, such as Colombia. The Government is aiming to make Panama an energy hub in Latin America and is looking for strategies to interconnect with neighbouring countries.[7] The Central American Electric Interconnection System (SIEPAC) was officially inaugurated in December 2014 and includes Guatemala, Honduras, Nicaragua, El Salvador, Costa Rica and Panama. With an investment of US$ 500 million, the system currently consists of one line of 230 kV with 300 MW of capacity. The second line (SIEPAC II) should come into operation in 2020. In 2016, through this system, Panama exported only 3.9 per cent of the electricity generated in the country and imported 0.3 per cent of the electricity consumed in the country.[26] Although electricity exchanges among the countries have been rather modest so far, this initiative has a great potential. There is also a plan for integration with Colombia with a capacity of 400 MW, which is expected to be completed by 2022 and represents a very interesting option for Panama due to price advantages.[16]

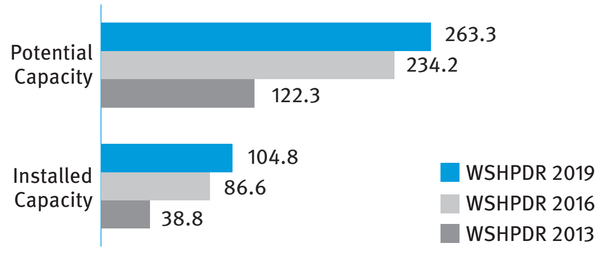
In Panama, a self-generation producer is defined as an entity producing and consuming electricity in the same place to meet its own needs. These electricity producers do not sell or transport the generated electricity to third parties; however, they can sell electricity surplus to other agents. Currently, these producers in Panama have an installed capacity of 7.2 MW.[8]

Electricity tariffs are set monthly by ASEP and include a variable price that fluctuates with the fuel market prices.[16] Between 2008 and 2017, electricity prices varied between 0.165 US$/kWh and 0.243 US$/kWh. However, when taking into account government subsidies, the prices varied between 0.158 US$/kWh and 0.219 US$/kWh.[18]

Small hydropower sector overview

Although the Latin American Energy Organization (OLADE) uses hydropower plants with a capacity up to 5 MW as the definition of small hydropower (SHP), SHP capacity up to 20 MW is considered for incentives under the legal framework of Panama.[19,20] For the sake of comparison with the previous reports, this report uses the definition of up to 10 MW for SHP, but data is provided for both the 10 MW and the 20 MW thresholds. Under the 10 MW definition, as of May 2018, there were 20 SHP plants, with a combined installed capacity of 104.8 MW, and 33 SHP plants with concessions granted or pending, with a combined capacity of 158.45 MW (Table 1).[21,22] In this report, the additional potential capacity is defined as the capacity of new SHP projects granted with concessions. Thus, total SHP potential stood at 263 MW. Compared to the results of the *World Small Hydropower Development Report (WSHPDR) 2016*, the installed and potential capacities increased by 21 and 12 per cent, respectively (Figure 3).

Figure 3.
Small hydropower capacities 2013/2016/2019 in Panama (MW)



Source: *WSHPDR 2016*,[2] ASEP,[21,22] *WSHPDR 2013*[27]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*

Table 1.
Small hydropower capacity in Panama

Plant size	*Capacity (MW)*		*Number of plants*	
	Installed	*Additional potential*	*Installed*	*Additional potential*
<10 MW	104.80	158.45	20	33
10 MW-20 MW	108.70	45.08	8	4
Total	**213.50**	**203.53**	**28**	**37**

Source: ASEP[21,22]

Renewable energy policy

The starting point for the promotion of renewable energy in Panama is included in Chapter II, Title VIII of Law No. 6 of 1997.[11] Renewable energy sources are defined in this law as geothermal power, wind power, solar power, biomass and hydropower. The high prices and the high levels of energy consumption led to the promulgation of Law No. 44 of April 2011.[23] This law aims to promote the diversity in the renewable energy sources mix and particularly focuses on wind power. The Long-Range Energy Alternative Planning Model is used to determine the possible scenarios of various energy mixes. Some articles of this law were modified by Law No. 13 of March 2013.[24]

The Paris Climate Change Agreement has also become a major factor incentivizing the use of renewable energy sources.[16] The Government of Panama has pledged to increase the share of renewable sources in electricity generation by 30 per cent by the end of 2050 compared to 2014.[26]

Legislation on small hydropower

The Government of Panama in 2004 established a legal framework for the hydropower sector by enacting Law No. 45, which established incentives for hydropower generation and other renewable energy sources as well as an extended scope for the SHP definition (up to 20 MW).[18] The incentives for small and mini-hydropower plants under this law include: no charge for electricity sold directly or indirectly by SHP plants up to 10 MW; exemptions for the first 10 MW delivered for 10 years by projects between 10 MW and 20 MW; fiscal exemptions for the importation of equipment, machinery, materials, etc.; fiscal incentives for projects up to 10 MW; and up to 25 per cent subsidy on the original investment calculated based on the reduction of CO_2 equivalent emissions per year.[18]

Barriers to small hydropower development

Although there is a favourable legal framework in place that grants fiscal incentives in order to develop SHP projects, the sub-sector development remains not very significant. The most important barriers are:

- Lack of a solid financial framework;
- Low level of investment in SHP projects;
- Dependence of remote communities on Government funds to obtain access to electricity.

References

1. Contraloría General de la República de Panamá, Instituto Nacional de Estadística y Censo (2017). Panama en Cifras 2012-2016. Available from https://www.contraloria.gob.pa/inec/archivos/P8551PanamaCifrasCompleto.pdf
2. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
3. Empresa de Transmisión Eléctrica, S. A. (ETESA) (2007). General Climate Description of Panamá. Available from http://www.hidromet.com.pa/clima_panama.phap
4. Autoridad Nacional del Ambiente (2011). Second National Communication before the United Nation Climate Change Framework Convention (UNCCFC), Panamá; 170 (in Spanish). Available from http://adaptation-undp.org/sites/default/files/downloads/panama_snc.pdf
5. Secretaria Nacional de Energía (SNE) (2017). El Mercado Eléctrico de la República de Panamá. 31 December 2017. Available from http://www.energia.gob.pa/energia/wp-content/uploads/sites/2/2018/04/Sector-El%C3%A9ctrico-Panam%C3%A1-171231-1.pdf
6. International Renewable Energy Agency (IRENA) (2018). Renewables Readiness Assessment. Panama. Available from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/May/IRENA_RRA_Panama_2018_En.pdf
7. Empresa de Transmisión Eléctrica, S. A. (ETESA) (2014). Plan Indicativo de Generación, Tomo III, Available from https://www.etesa.com.pa/documentos/Plan_Expansion_2014-2028/Tomo_III_Plan_de_Transmision_2014-2028.pdf
8. Empresa de Transmisión Eléctrica, S. A. (ETESA) (2017). Plan de Expansión del Sistema Interconectado Nacional 2017-2031, Tomo II. Plan Indicativo de Generación. Available from https://www.etesa.com.pa/documentos/tomo_ii__plan_indicativo_de_generacin_20172031_25.pdf
9. Secretaría Nacional de Energía (SNE) (2011). Law No. 43-2011. Available from http://www.energia.gob.pa/pdf_doc/MarcoLegal/A-SNE/Ley43-2011(GO26771).pdf
10. Oficina de Electrificación Rural (OER), Ministerio de la Presidencia (2013). Memoria noviembre 2013 – octubre 2014. Available from http://issuu.com/oerpanama/docs/memoria_oer_nov._2013_-_oct._2014/0
11. Secretaría Nacional de Energía (SNE) (1997). Ley No. 6-1997. Available from: http://www.energia.gob.pa/pdf_doc/MarcoLegal/B-Sector-Electrico/Ley6-1997(GO26871-C).pdf
12. Secretaría Nacional de Energía (SNE) (2013). Ley No. 18-2013. Available from http://www.energia.gob.pa/pdf_doc/MarcoLegal/B-Sector-Electrico/Ley18-2013(GO27254).pdf
13. Secretaría Nacional de Energía (SNE) (1998). Decreto Ejecutivo 22-1998. Available from http://www.energia.gob.pa/pdf_doc/MarcoLegal/B-Sector-Electrico/DE22-1998(GO23572).pdf
14. Empresa de Transmisión Eléctrica, S. A. (ETESA) (2018). Plan de Expansión del Sistema Interconectado Nacional 2017 – 2031.

Available from https://www.etesa.com.pa/plan_expansion.php

15. Index Mundi (2018). Consumo de electricidad per cápita – Centroamérica y el Caribe. Available from https://www.indexmundi.com/map/?t=0&v=81000&r=ca&l=es
16. Secretaría Nacional de Energía (SNE (2016). Plan Energético Nacional 2015-2050. Available from http://www.energia.gob.pa/energia/wp-content/uploads/sites/2/2017/06/Plan-Energetico-Nacional-2015-2050-1.pdf
17. National Authority of Public Services (ASEP) (2018a). Official website. Available from https://www.asep.gob.pa/?option=com_content&view=article&id=147&Itemid=134
18. National Authority of Public Services (ASEP) (2018b). Precio Promedio Global de la Electricidad. Available from https://www.asep.gob.pa/wp-content/uploads/electricidad/tarifas/05_informacion_costo_sector/precio_promedio_global.pdf
19. Oficina de Electrification Rural (OER) (2014). The potential of small hydro for rural electrification. Available from http://www.ruralelec.org/fileadmin/DATA/Documents/06_Publications/Position_papers/ARE_Small_Hydropower_Position_Paper_2014.pdf
20. Secretaría Nacional de Energía (SNE) (2004). Ley No.45. August 4 – 2004. Available from http://www.asep.gob.pa/images/electricidad/Legislacion/LEY%20DE%20INCENTIVOS.pdf
21. National Public Service Authority (ASEP) (2018). Concesiones en operación. Available from http://www.asep.gob.pa/images/electricidad/concesiones_licencias/Hidroelectricas_Operacion.pdf
22. National Public Service Authority (ASEP) (2018). Concesiones otorgadas y en trámite. Available from http://www.asep.gob.pa/electric/Anexos/conce_otorgadas_tramite.pdf
23. Secretaría Nacional de Energía (SNE) (2011). Ley No. 44. April 25-2011. Gaceta Oficial No. 26,771
24. Secretaría Nacional de Energía (SNE) (2011). Ley No. 18. March 26-2013. Gaceta Oficial No. 27,254
25. World Bank (2006). Panama. Available from https://data.worldbank.org/country/panama
26. Secretaría Nacional de Energía (SNE) (2017) Actualización del Plan Energético Nacional Available from http://www.energia.gob.pa/energia/wp-content/uploads/sites/2/2018/04/PEN-2017-Versión-Final.pdf
27. LIU, H., Masera, D. and Esser, L., eds. (2013). World Small Hydropower Development Report 2013, United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org

2.3 South America

Cleber Romao Grisi, WHITEnergy Bolivia

Introduction to the region

The South America region comprises 12 sovereign countries: Argentina, the Plurinational State of Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay and the Bolivarian Republic of Venezuela; and four dependent territories: French Guiana administrated by France, the Falkland Islands, and South Georgia and the South Sandwich Islands under the British Government, and Bouvet Island.[4] This report covers all South American sovereign countries and French Guiana. Compared to the *World Small Hydropower Development Report (WSHPDR) 2016*, two new countries have been included in this report, Suriname and Venezuela. An overview of the region is given in Table 1.

South America is comprised of three topographic regions: river basins, coastal plains, and mountains/ highlands. Coastal plains and mountains generally run in the north-south direction, while highlands and river basins generally run in the east-west direction. The western part is dominated by the Andes mountains, where temperatures fall below 0 °C, and the Pacific coast, where rainfall can be as low as 1 mm per year (in the Atacama Desert). The eastern region is ruled by tropical rainforests and vast grasslands, where the average temperature is about 30 °C and rainfall can exceed 5,000 mm per year.[5,6]

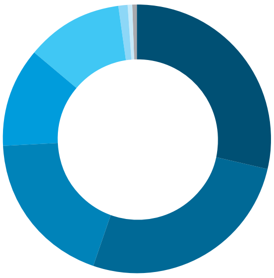
There are approximately 421 million inhabitants in these countries. Most of this population lives near the continent's western and eastern coasts, while the interior and the far south are sparsely populated. Approximately 85 per cent of the total population lives in urban areas.[4] In South America, around 90 per cent of the rural population has electricity access and the urban electrification rate is about 99 per cent.[5]

Electricity in the region is produced from different sources, with hydropower and thermal power being the dominant technologies. Other sources include nuclear power, wind power and biomass. Installed capacity and electricity production have increased in all South American countries since the *WSHPDR 2016*. The South American region has an estimated total installed capacity of 313 GW, of which 54 per cent (168 GW) comes from hydropower. The hydropower installed capacity and hydropower generation have increased by 22 per cent and 12 per cent, respectively, compared to the *WSHPDR 2016*.

South America hosts the Amazon, Orinoco, and Paraguay/Paraná river basins, covering almost 7 million km^2, 948,000 km^2 and 2.8 million km^2, respectively.[6] These watersheds make this region attractive and suitable for hydroelectric development of varying capacities.

All countries included in the *WSHPDR 2019* have a potential capacity for small hydropower (SHP) development. There is a total of 806 MW of SHP installed capacity up to 10 MW (Table 2), and only 2.8 per cent of the known SHP potential (28,483 MW) has been utilized. Chile and Colombia alone account for 56 per cent of this capacity (Figure 1). However, it should be noted that this total does not include the installed capacities of Brazil and Peru, since data on SHP equal or less than 10 MW is not available. Following the local definitions, Brazil is the leader in the region in terms of installed capacity, with 5,670 MW of SHP (up to 30 MW) (Table 2).

Figure 1.
Share of regional installed capacity of small hydropower up to 10 MW by country in South America (%)



Source: *WSHPDR 2019*[3]

Note: Does not include Brazil and Peru, as data on capacity up to 10 MW is not available.

Note: The use of the term 'country' does not imply an opinion on the legal status of any country or territory.

Table 1.
Overview of countries in South America

Country	*Total population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Argentina	43.8	8	100	38,200	145,447	10,118	38,529
Bolivia	11.1	31	90	1,855	8,759	483	1,715
Brazil	207.7	14	100	158,260	579,000	101,289	380,900
Chile	17.6	13	100	23,900	74,647	6,710	21,786
Colombia	48.3	20	99	17,391	67,000	11,834	57,000
Ecuador	16.8	36	100	7,607	27,314	4,418	15,834
French Guiana	0.2	16	N/A	300	941	119	439
Guyana	0.8	73	84	163	809	0	0
Paraguay	6.8	39	98	8,835	59,685	8,810	59,684
Peru	32.2	22	95	14,518	51,700	5,189	24,172
Suriname	0.6	34	85	501	2,258	307	1,356
Uruguay	3.4	5	100	4,546	14,364	1,538	7,469
Venezuela	32.0	12	100	36,561	115,600	16,905	67,633
Total	**421.3**	-	-	**312,637**	**1,147,524**	**167,721**	**676,517**

Source: *WSHPDR 2016*,[2] *WSHPDR 2019*,[3] WB,[7] WB,[8] CNE,[9] IEA[10]

Small hydropower definition

The definition of SHP varies across the countries of South America, from 5 MW in Bolivia and Guyana to 50 MW in Argentina, Paraguay and Uruguay. In most cases, there are no limits for categorizing small, micro- and pico-hydropower. In some countries, SHP remains undefined (Table 2).

Regional small hydropower overview and renewable energy policy

Countries in South America started to develop SHP projects in the late 19th century.[11] However, project development has been slow due to the higher costs compared to large or medium-scale hydropower schemes, and a lack of appropriate regulations related to taxes, tariffs, subsidies and concessions, environmental permits and social acceptance.

Most countries in South America, including Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador and Peru, have renewable energy policies to encourage and provide benefits for developing renewable energy projects, particularly SHP schemes. Some benefits offered to SHP projects in the region include:

- Exemption or reduction of taxes for importing equipment and construction
- Power Purchase Agreements to secure the energy purchase price in a mid- or long-term agreement, which allow investors to pay the generation costs and to receive an acceptable investment return rate
- Favourable conditions to meet Government, authorities or any other regulatory institution requirements to acquire the necessary permissions to develop the project
- Financing with suitable conditions for SHP projects.

Ecuador is one of the very few Latin American countries that implemented a **feed-in tariff (FIT)** scheme for renewable energy, which applies to SHP up to 10 MW.

With 806 MW of installed capacity, SHP (up to 10 MW) accounts for 0.5 per cent of the total installed hydropower capacity in the region. The known SHP potential (up to 10 MW) is estimated at 28,483 MW, of which approximately 2.8 per cent has already been developed. This estimate, however, does not take into account the potential of Brazil, which is estimated based on the local definition of SHP up to 30 MW and is reported to stand at 20,506 MW, and the potential of Peru, which is estimated to be at least 3,500 MW as per the local definition of SHP up to 20 MW (Figure 2). The SHP installed capacity of the South America region has increased by approximately 5 per cent compared to the *WSHPDR 2016*, with the most significant changes observed in Bolivia, Brazil and Chile (Figure 3).

Table 2.
Small hydropower capacities in South America (local and ICSHP definition) (MW)

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed (<10 MW)*	*Potential (<10 MW)*
Argentina	up to 50	410.2	N/A	97.0	430.0
Bolivia	up to 5	N/A	N/A	152.8	200.0
Brazil	up to 30	5,670.0	20,506.0	N/A	N/A
Chile	up to 20	488.0	10,825.0	236.0	2,113.0
Colombia	up to 10	214.0	25,000.0	214.0	25,000.0
Ecuador	up to 10	98.2	296.6	98.2	296.6
French Guiana	up to 10	6.3	6.3*	6.3	6.3*
Guyana	up to 5	0.0	24.2	0.0	92.1
Paraguay	up to 50	0.0	116.3	0.0	86.3
Peru	up to 20	363.0	3,500.0	N/A	N/A
Suriname	-	-	-	1.0	2.7
Uruguay	up to 50	0.0	232.0	0.0	207.8
Venezuela	-	-	-	0.3	48.0
Total		**-**	**-**	**806**	**28,483**

Source: *WSHPDR 2019*,[3] IMFIA[12]

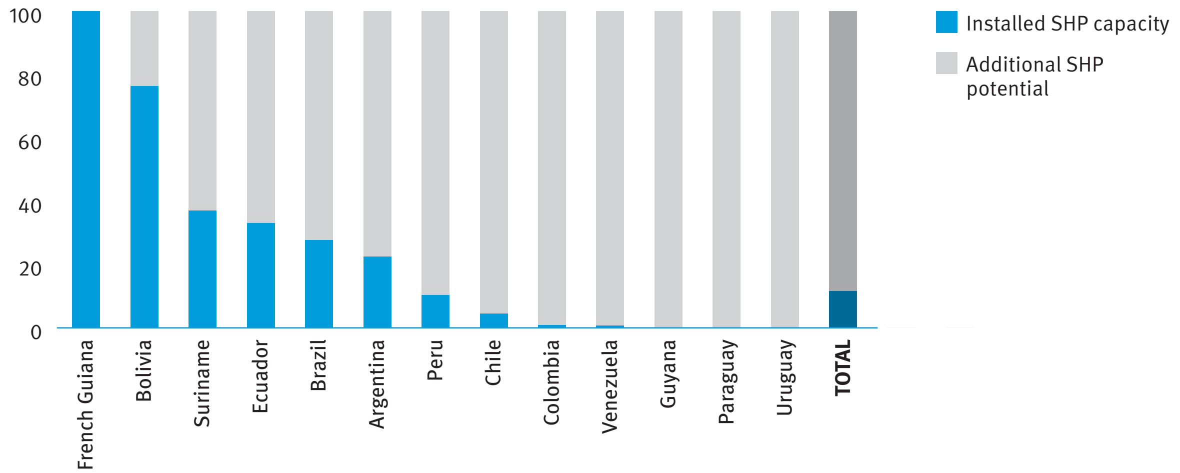
Note: * The estimate is based on the installed capacity as no data on potential capacity is available.

An overview of SHP in the countries of South America is outlined below. The information used in this section is extracted from the country profiles, which provide detailed information on SHP capacity and potential, among other energy-related information.

In **Argentina,** the installed capacity of SHP following the local definition of up to 50 MW is 410 MW. For SHP up to 10 MW, the installed capacity is 97 MW. Multiple renovation projects of SHP plants are planned for the period between 2019 and 2023. It is thus expected that the installed capacity will increase considerably in the coming years. There is a great potential for SHP in Argentina, which is estimated at 430 MW.

Bolivia has 33 SHP plants (up to 10 MW). Their total installed capacity is 152.8 MW, while the available capacity is 124.8 MW. In rural areas, there are many SHP plants supplying small villages or industry, most of which are out of service or in a poor condition and could be eligible for refurbishment. The Government's strategic plan foresees the development of hydropower below 30 MW and includes SHP projects of approximately 30 MW for grid connection and another 20 MW for isolated networks. This brings the total known potential of SHP in Bolivia up to approximately 200 MW.

Figure 2.
Utilized small hydropower potential by country in South America (local SHP definition) (%)



Source: *WSHPDR 2019* [3]

Note: This Figure illustrates data for local SHP definitions or the definition up to 10 MW in case of the absence of an official local definition. For Argentina and Bolivia, the data is presented for the SHP definition up to 10 MW due to the absence of data on installed and/or potential capacity according to the local definitions. For French Guiana, additional potential is not known.

According to the latest data, there are 1,098 SHP plants up to 30 MW in operation in **Brazil** with a combined installed capacity of 5,670 MW. The potential is estimated at 20,506 MW, including 7,021 MW of the potential available in the short term and 1,856 MW already suitable for auctions. However according to the Brazilian Decennial Plan for Energy Expansion 2026, the installed capacity of SHP is predicted to reach 6,658 MW in 2020 and 7,858 MW in 2025. Thus, indicating that the relative share of SHP in the country's energy mix is not expected to grow substantially.

In **Chile**, the available installed capacity of SHP up to 20 MW is 488 MW. Additionally, in 2018 there were 46 MW of SHP under construction and 824 MW were approved for development. For SHP up to 10 MW, the total installed capacity was estimated at 236 MW and the potential at 2,113 MW. The increase in the installed capacity compared to the *WSHPDR 2016* was mainly due to regulatory changes that simplified the processing of projects under 9 MW and particularly for those under 1.5 MW.

The SHP installed capacity of **Colombia** is 214 MW. A decrease of 14 per cent, compared to the *WSHPDR 2016*, is based on more accurate data. The SHP potential is estimated at 25,000 MW, of which less than 0.9 per cent has been developed. From the beginning of 2016 until the end of May 2019, 23 applications for SHP certification were received, of which 17 projects with a combined capacity of 54.2 MW were approved.

The total installed capacity of SHP plants of up to 10 MW in **Ecuador** stands at 98.2 MW, from 37 plants. Some of the most recently commissioned plants include the Victoria SHP plant of 10 MW, the Hydrotambo plant of 8 MW and the Central Alazan plant of 6.23 MW. A number of new projects have been approved for construction by the Government. Based on the conducted feasibility studies, the potential capacity is estimated at 296.6 MW.

In **French Guiana**, the installed capacity of SHP remains at 6.3 MW, similar to figures from the *WSHPDR 2016*. The two SHP plants in operation are: La Mana, with an installed capacity of 4.5 MW and Saut-Maripa, with a capacity of 0.88 MW. The potential SHP capacity figures for French Guiana are unavailable, but several sites were identified on the Mana, Compté and Approuague rivers. These sites might produce 7 MW to 15 MW in the near future. However, the lack of funding in the field of SHP as well as the growing popularity of electricity generated through solar power, makes investment in this sector less probable.

Although **Guyana** has a track record of hydropower use, currently not a single hydropower plant is operational. Nevertheless, hydropower initiatives are currently considered and supported by the Government of Guyana. The potential capacity is estimated to be 24.2 MW for the 5 MW threshold and 92.1 MW for the 10 MW threshold.

There are no SHP plants (up to 50 MW) in operation in **Paraguay**. The country has an enormous hydropower potential, but total SHP potential remains unknown. Based on the projects planned to be completed by 2025, it is possible to conclude that there is at least 116.3 MW of undeveloped potential. This capacity comes from 18 SHP projects (up to 50 MW) planned to be developed across the country for decentralized electricity generation.

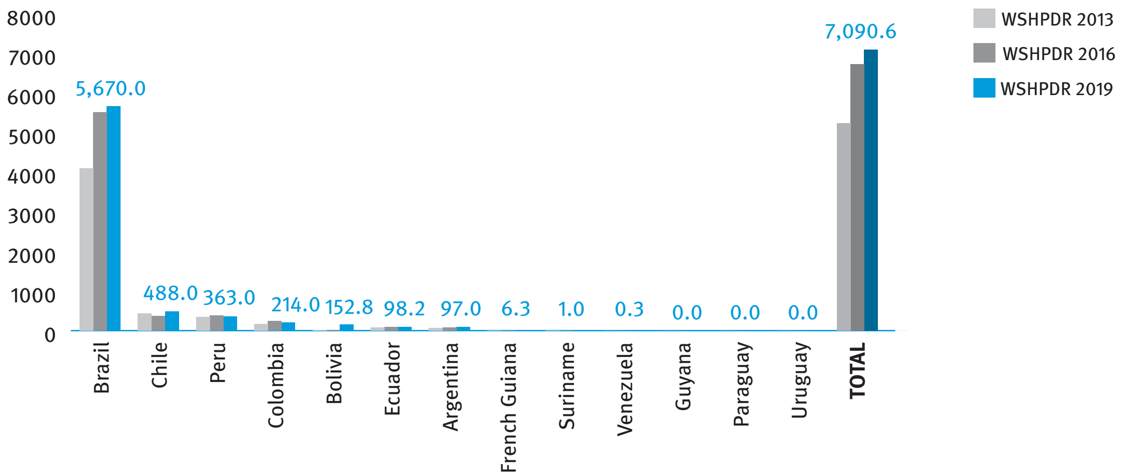
Peru has a significant SHP potential (up to 20 MW), which is estimated to be at least 3,500 MW based on a portfolio of potential hydropower projects compiled by the Ministry of Energy and Mines in 2016. The total installed capacity for all SHP plants up to 20 MW is 362.9 MW. Compared to the *WSHPDR 2016*, the reported installed capacity decreased by 7 per cent since the new reported values were obtained from more accurate data.

The installed SHP capacity of **Suriname** (up to 10 MW) is 1 MW. Based on the planned plants, the potential is estimated to be at least 2.7 MW, but it is expected to be higher. Nonetheless, the Rural Small Hydro Project was cancelled due to budget limitations.

Uruguay has only large-scale hydropower plants with capacities above 50 MW. The potential of SHP up to 50 MW is estimated at 232 MW, which comes from 70 potential sites, including existing irrigation dams. Out of these sites, 68 have a capacity less than 10 MW, with their combined capacity being 207.8 MW.

There are several SHP plants in **Venezuela**, all of them below 1 MW. The total installed capacity is at least 295 kW. The potential is estimated at 48 MW, and thus less than 1 per cent of the potential has been developed so far.

Figure 3.
Change in installed capacity of small hydropower from *WSHPDR 2013* to *2019* by country in South America (MW)



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

Note: *WSHPDR* stands for *World Small Hydropower Development Report.* For Brazil, data are for SHP up to 30 MW; for Chile and Peru, data are for SHP up to 20 MW; for other countries data are for SHP up to 10 MW.

Barriers to small hydropower development

South America has an enormous hydropower potential to develop large, medium and small hydropower schemes. However certain technical, regulatory and policy issues may interfere with the implementation of SHP projects. One of the most common limitations to SHP development across the South American region is the lack of, or poor, policy and regulatory frameworks, as well as a lack of incentives. There are political constraints and structural limitations within the governmental agencies that are responsible to enforce policies or regulations to provide a suitable framework for the development of SHP projects. Renewable energy projects are also hindered by bureaucracy and lengthy processes of obtaining permits.

In addition to the above, in **Argentina** the limited availability of local funding is perceived as a risk for foreign investors. Local funding is hindered by the limited number of local banks and the lack of liquidity experienced by the commercial banks. The difficulty in securing capital at reasonable costs strongly hinders the volume of investment, despite the country's resources and high potential.

The Government of **Bolivia** prioritizes the development of large hydropower for exporting electricity to the neighbouring countries. The quality of hydrological, climate and other data remains rather poor, especially for rural areas. Furthermore, the low energy prices are not very attractive for private investors, the process of establishing a private company can be rather difficult and hydropower projects risk to be cancelled due to social acceptance issues.

In **Brazil**, other renewable energy sources, mainly wind power, receive more incentives. Other barriers include the high costs of constructing and operating SHP plants, the strict requirements for environmental licensing process for plants between 10 MW and 30 MW as well as the generally negative perception of hydropower among the population.

Hydropower developement in **Chile** has to compete with other uses of water. Additionally, there is a lack of information within communities about the costs, potential risks and real benefits associated with hydropower projects, which generates mistrust. The communities at large feel left out of the planning of hydropower projects. Also, SHP projects tend to be located in areas far from transmission lines, which often makes them unfeasible.

Hydropower generation in **Colombia** is impacted by a reduced rainfall due to climatic variations, which encourages the Government to reduce concrete SHP promotion strategies and incentives. Furthermore, financial support for potential SHP investors is limited and the technical norms have not been defined and standardized. Finally, local political instabilities also hinder foreign investment as many sites are located in areas where guerrilla activities have taken place.

Dependency on large hydropower makes large projects a priority for the Government of **Ecuador**, leading to a very limited SHP investment. There is also a lack of detailed data in regard to the economic and technical potential of SHP.

In **French Guiana**, the focus more recently has been on solar and biomass development. In general, the flat topography as well as the natural climatic variations make it more difficult to develop SHP. Foreign investment in renewable energy projects in the country has been deterred by geographical isolation, high demographic growth and high crime rates.

There is a vast hydropower potential in **Guyana**, including the possibility to link several projects together. Currently, the viability of projects is jeopardized by high development costs due to the great distances between hydropower sites and load centres, and a lack of infrastructure.

In **Paraguay**, due to the monopoly of the state-owned utility over the electricity sector and and the insufficient demand independent power, producers have no incentives to enter the SHP market.

In **Peru**, investment costs tend to be high due to the need to develop infrastructure. There is also limited local expertise in renewable energy technologies as well as an absence of financial experience in the renewable energy market.

In **Suriname**, low electricity tariffs and the lack of funding for hydropower projects are the major barriers to renewable energy development.

In **Uruguay**, the flat terrain favours the development of solar and wind power, rather than SHP. There is also a fundamental gap in experience and knowledge in relation to planning, implementation, operation and maintenance of SHP plants. Also, socio-economic and environmental assessments of SHP projects might be too costly.

In **Venezuela**, large hydropower is considered much more profitable than SHP. Due to multiple complaints and protests resulting from the lengthy electricity crisis, the Government mostly considers projects that could offer higher electricity coverage for the population. There is also a lack of local expertise in the SHP sector, as well as limited information on SHP potential and existing plants.

References

1. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
2. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
3. LIU, D., LIU, H., WANG, X., and Kremere, E., eds. (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
4. United Nations Statistics Devision (n.d.). *Methodology. Geographic Regions.* Available fromhttps://unstats.un.org/unsd/methodology/m49/
5. World Atlas (n.d.). *South America.* Available from http://www.worldatlas.com/webimage/countrys/sa.htm.
6. National Geographic (n.d). *South America: Physical Geography.* Available from https://www.nationalgeographic.org/encyclopedia/south-america-physical-geography/.
7. World Bank (2017). Rural population (% of total population). Available from https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS
8. World Bank (2016). *Access the electricity (% of population).* Available from https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS
9. National Energy Commission (CNE)(n.d.). *Statistics.* Available from https://www.cne.cl/en/estadisticas/electricidad/
10. International Energy Agency (IEA)(n.d.). *Electricity generation by fuel. Venezuela 1990-2016.* Available form https://www.iea.org/statistics/?country=VENEZUELA&year=2016&category=Electricity&indicator=ElecGenByFuel&mode=chart&dataTable=ELECTRICITYANDHEAT
11. Alarcón, A.D. (2018). *El Sector hidroeléctrico en Latinoamérica - Desarrollo, potencial y perspectivas.* BID.
12. Faculty of Engineering, University of the Republic (IMFIA) (2013). *Generación Hidroeléctrica en pequeña escala.* Agencia Nacional de Investigacion e Innovacion (ANII). Available from http://www.dne.gub.uy/documents/48237/4406457/PCH%20Generacion.pdf

2.3.1

Argentina

Raúl Pablo Karpowicz, Colegio de Ingenieros Civiles de la Provincia de Córdoba

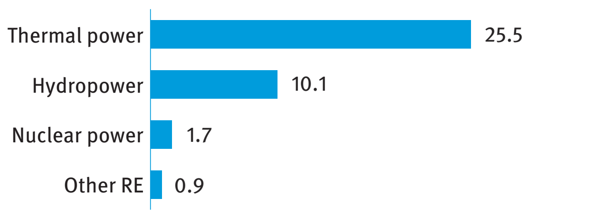
Key facts

Population	43,847,430[1]
Area	2,780,000 km[2]
Climate	The country has a diverse climate due to its high altitude and diverse topography. In Argentina, January is the warmest month, and June and July are the coldest. As the prevailing western winds lose their moisture and descend into Argentina, temperatures increase as humidity decreases. The north of the country has a warm and humid sub-tropical climate. Central Argentina has a temperate-continental climate, with very hot summers and mild winters. The south of the country has a sub-arctic climate and is directly influenced by the western winds.[2]
Topography	The terrain comprises rich plains of the Pampas in northern half of the country, flat to rolling plateau of Patagonia in the south, and rugged Andes along the western border. The highest point is Aconcagua, at 6,960 metres.[2]
Rain pattern	Rainfall is variable, depending on the location and elevation. The north receives rain throughout the year, with an annual average of around 750 mm. In central Argentina, the average annual rainfall varies between 1,000 mm in the east and 500 mm in the west, towards the Andes. The south receives the least rainfall, with a low average of 200 mm.[2]
Hydrology	The major rivers in Argentina include the Pilcomayo, Paraguay, Bermejo, Colorado, Río Negro, Salado, Uruguay and Paraná, the largest river. The latter two flow together before meeting the Atlantic Ocean, forming the estuary of the Río de la Plata. Regionally important rivers are the Atuel and the Mendoza in Mendoza province, the Chubut in Patagonia, the Río Grande in Jujuy, and the San Francisco River in Salta.[2]

Electricity sector overview

The total installed capacity in Argentina in 2015 was 38.2 GW, consisting of thermal power (25.5 GW), hydropower (10.1 GW), nuclear power (1.7 GW), and the remainder (0.9 GW) was from other renewable energy (RE) sources (Figure 1).[7]

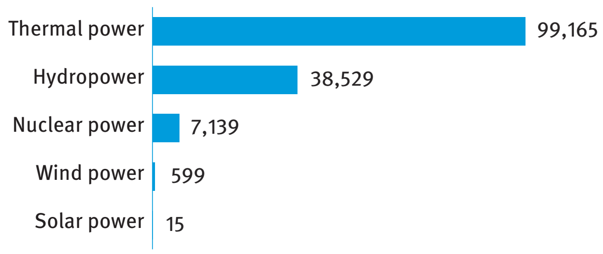
Figure 1.
Installed electricty capacity by source in Argentina (GW)



Source: CIA data[7]

The total electricity generation in 2015 was 145,447 GWh, with thermal power accounting for 85,431 GWh, hydropower for 38,493 GWh, nuclear energy for 7,139 GWh, wind power for 599 GWh and solar power for 15 GWh. From auto-producers, combustible fuels accounted for another 13,734 GWh and hydropower for 36 GWh.[8] The figure below shows the total electricity generation by source. The large increase in thermal production is due to unavailability of data from auto-producers in the previous years. Data about electricity generation through other renewable energy sources apart from hydropower was also recently made available.

Figure 2.
Annual electricity generation by source in Argentina (GWh)



Source: UN[8]

Compañía Administradora del Mercado Mayorista Eléctrico (CAMMESA) is the administrator of the electricity market. The National Electricity Regulatory Commission (ENRE) is an independent entity within the State Secretariat for Energy. ENRE is responsible for regulating the energy industry.

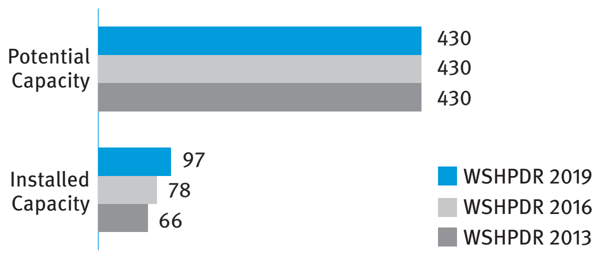
The electrification rate in Argentina was 100 per cent, as of 2017.[9] The average electricity tariff is US$ 0.09 per kWh.

Small hydropower sector overview

In Argentina, the installed capacity of small hydropower (SHP) is 410.24 MW (for plants under or equal to 50 MW), according to the data released in December 2017 by CAMMESA, the Company that manages the Wholesale Electricity Market.[3] CAMMESA is a non-profit private company in Argentina (80 per cent is owned by Agents of the wholesale electricity market, while the remaining 20 per cent belongs to the Ministry of Energy). The total installed capacity for hydropower is 10,118 MW, according to 2016 World Energy Council data. Therefore, SHP accounts for roughly 4.05 per cent of total hydropower installed capacity. Respecting the definition of the *World Small Hydropower Development Report* (WSHPDR), the installed capacity of small hydropower plants up to 10 MW is 97 MW. The observed increase is due to new data made available by the Government of Argentina. The 97 MW of installed capacity generates a total of 272 GWh electricity.[10]

Multiple renovation projects of small hydropower plants are planned for the period between 2019 and 2023. It is thus estimated that the installed capacity of small hydropower will increase considerably by 2023. In 2017, new small hydropower plants of 1.5 MW, 2 MW, 1.2 MW and 1.42 MW were installed. Additionally, the Government announced that, as part of the RenovAr plan, modernization work on existent renewable energy plants will commence.[3,4] There are no updates on the potential capacity for small hydropower in Argentina, compared to the previous reports.

Figure 3.
Small hydropower capacities 2013/2016/2019 in Argentina (MW)



Source: *WSHDR 2013*,[11] *WSHPDR 2016*,[6] CAMMESA[3]

Note: Current country definition refers to plants < 50 MW; data in the figure represents plants up to 10 MW.

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016 and WSHPDR 2019.*

There is a great potential for small hydropower in Argentina. A national inventory of small hydropower facilities was conducted by the Ministry of Energy, with approximately 116 potential projects, at different levels of development. A plan for the dissemination of SHP has been proposed. Firstly, it will be necessary to conduct thorough impact studies of the hydrological, geological, geotechnical and environmental situation. Few studies were conducted so far and there are numerous plants and facilities which require modernization. Secondly, it is also recommended to evaluate additional environmental benefits, the social cost of externalities, as well as the supply of drinking water with the aim of including them in the remunerations for potential investors and companies interested. In addition, ensuring all provinces of Argentina accept and implement the "law of distributed generation" may further enhance the development of small hydropower in the country.

Renewable energy policy

Argentina decided to promote renewable energy by implementing the RenovAr programme, supported by the World Bank. At the beginning of its mandate, the current Government announced an energy emergency and established as a state policy the development of renewable energy sources to contribute to the growth of the local market for clean energy. In line with this purpose, 2017 was named the "Year of Renewable Energy", considering it as a key period in the pursuit of the aforementioned objectives.[4]

Prior to that, in 2015, Law No. 27.191, the "National Promotion Regime for the Use of Renewable Sources for the Production of Electric Power" was enacted and promulgated unanimously, declaring the generation of electricity from RE sources a national interest. Renewables will be mandatory for the supply of public services. Research on technological development and manufacturing of equipment will be prioritized and conducted.[4]

The law established that 8 per cent of the national electricity had to originate from renewable sources (excluding large hydropower plants). This target was set for 31 December 2018, according to the Government of Argentina. A new target for 2025 was also established, with the country aiming to further diversify its energy matrix by reaching 20 per cent of electricity generated through renewable energy sources, excluding large hydropower. More than 8,000 large consumers already commenced the procedures to adapt and comply with the new renewable energy development plans. The Government's attempts to reach these targets without negatively affecting the energy sector provided the justification for the continuous, recent increase in prices. The Government of Argentina also lowered the costs of equipment for renewable energy installations, mainly focusing on solar photovoltaics and wind power. Measures such as the reduction and cancellation of import tariffs and other tax benefits will be taken against users who do not comply with the renewable energy quota.[4]

The RenovAr Plan is controlled by the Ministry of Energy and Mining and promotes actions aiming to encourage large-scale investments in renewable energy projects. The RenovAr was launched in different stages, officially named Rounds: Round 1, Round 1.5 and Round 2. The differences between these stages were the modifications in the available quotas for the different types of renewables and the adjustments of the referential prices. Referential prices for energy depend on its source – wind, solar photovoltaics, biomass or hydropower.

Table 1.
Small hydropower awarded by RenovAr in 2017

Identification	*Project name*	*Proposed by*	*State*	*Region*	*Round*	*Power (MW)*
PAH-05	P.A.H. Río Escondido	PATAGONIA ENERGíA	Río Negro	Comahue	1	7.00
PAH-03	P.A.H. Dique Tiburcio Benegas	EMESA / CONST. ELECT. DEL OESTE	Mendoza	Cuyo	1	1.65
PAH-02	P.A.H. Canal Cacique Guaymallén - Salto 6	EMESA / CONST. ELECT. DEL OESTE	Mendoza	Cuyo	1	1.01
PAH-01	P.A.H. Canal Cacique Guaymallén - Salto 8	EMESA / CONST. ELECT. DEL OESTE	Mendoza	Cuyo	1	1.20
PAH-04	P.A.H. Triple Salto Unificado	EMESA / CONST. ELECT. DEL OESTE	Mendoza	Cuyo	1	0.51
PAH-709	P.A.H. Boca del Rio	EPEC	Córdoba	Centro	2	0.50
PAH-708	P.A.H. Cruz del Eje	EPEC	Córdoba	Centro	2	0.50
PAH-710	P.A.H. Pichanas	EPEC	Córdoba	Centro	2	0.50
PAH-700	P.A.H. Las Tunas	CONSTRUCCIONES ELECTROMECÁNICAS DEL OESTE S.A.	Mendoza	Cuyo	2	10.00
PAH-702	P.A.H. Salto 7	CONSTRUCCIONES ELECTROMECÁNICAS DEL OESTE S.A.	Mendoza	Cuyo	2	1.20
PAH-712	P.A.H. Lunlunta	NEXO ENERGIA S.A.	Mendoza	Cuyo	2	6.34
PAH-715	P.A.H. Salto 11	SKRU S.A.	Mendoza	Cuyo	2	0.51
PAH-714	P.A.H. Salto 40	SKRU S.A.	Mendoza	Cuyo	2	0.52
PAH-705	P.A.H. Salto De La Loma	LATINOAMERICANA DE ENERGÍA S.A.	San Juan	Cuyo	2	0.70

Source: MINEM[4]

Projects that were not offered an award in regular contests were suggested to improve their proposals. This announcement encouraged the proposal of multiple small hydropower projects, which received an award and the possibility to access the World Bank payment scheme for the generated energy. Table 1 describes the SHP projects awarded by RenovAr in 2017. [4]

The calls for the project proposals are mainly aimed at promoting photovoltaics and wind power offers that have exceeded the available quotas. Many of these proposals were not considered due to the lack of access to the interconnected electrical high voltage system. Bidders had to negotiate their access to the interconnected system in order to be granted an award.

The RenovAr initiative resulted in 14 small-scale hydropower projects awarded at a weighted average price of 0.101 US$/kWh. In addition, a 2,466 MW wind power plan and a 1,732 MW solar power plan were also awarded. In the updated and finalized RenovAr Round 2, the median award prices for each renewable technology without added value tax were as follows: wind power 40.6 US$/MWh, solar power 42.30 US$/MWh, biomass 126.3 US$/MWh, biogas 169.0 US$/MWh, biogas landfill 129.7 US$/MWh and SHP 100.9 US$/MWh.12

Barriers to small hydropower development

Due to a great SHP potential, SHP is considered a promising source of energy for national development, but a number of very diverse barriers hinder its realization. There are political constraints and structural limitations within the governmental agencies, responsible for establishing policies that provide solutions to these problems. It is necessary to apply instruments that help formulate and implement an energy policy that includes RE.

Some of the structural limitations are include:
- Bureaucracy and the different jurisdictions involved;
- National laws related to the use of water should be considered;
- Land permits and the lengthy time needed for obtaining them;
- Lack of continuity in the employment of specialized personnel.[6]

At the moment, the regulatory framework remains insufficient, however there are upcoming proposals contributing to speeding up the SHP development in Argentina. The proposed establishment of the ICSHP sub-centre, in the Province of Cordoba as well as the future implementation of the National Law of Distributed Generation are plans that will significantly improve the small hydropower sector. Recently, a National Centre of Renewable Energy was also inaugurated.

The limited availability of local funding is perceived as a risk for foreign investors. Local finance is hindered by the limited number of local banks and the lack of liquidity experienced by the commercial banks. Furthermore, the difficulty in securing capital at reasonable costs strongly hinders the volume of investment, despite the country's resources and high potential.[6]

References

1. The World Bank (2014). *Population, total.* Available from http://data.worldbank.org.
2. United Nations Food and Agriculture Organization (2015). *Argentina*. Aquastat database. Available from www.fao.org/nr/water/aquastat/countries_regions.
3. Cammessa (2017). Base Generadores Hidro (HI). Available from http://portalweb.cammesa.com/memnet1/pages/descargas.aspx
4. Ministry of Energy and Mines (MINEM) (2017). Argentina: Programa RenovAr cerro exitosamente su ronda 1 con la adjudicación de 29 proyectos por 1142 MW. Available from https://www.minem.gob.ar/prensa/25369/programa-renovar-cerro-exitosamente-su-ronda-1-con-la-adjudicacion-de-29-proyectos-por-1142-mw
5. Ministry of Energy and Mines (2017) . Proyectos adjudicados del programa RenovAr. Available from https://www.minem.gob.ar/www/833/25897/proyectos-adjudicados-del-programa-renovar
6. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
7. Central Intelligence Agency (2015). South America: Argentina. Available from https://www.cia.gov/
8. United Nations Data (2015). Total Electricity Gross Production: Argentina. Available from http://data.un.org/
9. World Bank Data (2014). Access to electricity (% of population). Available from https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS
10. International Renewable Energy Agency (IRENA) (2017). Renewable Energy Statistics. Acailable from http://www.irena.org/-/media/Files/IRENA
11. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013***.** United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from: www.smallhydroworld.org. Accessed 15 April 2018
12. Ministry of Energy and Mines (MINEM) (n.d.). Precios adjudicados del Programa RenovAr. Rondas 1, 1.5 y 2. Available from https://www.minem.gob.ar/www/833/25871/precios-adjudicados-del-programa-renovar

2.3.2

Bolivia (Plurinational State of)

Cleber Romao Grisi, WHITEnergy Bolivia

Key facts

Population	11,138,234[1]
Area	1,098,581 km^2 [1,3]
Climate	There are three main geographic zones: the Andean zone, the Sub-Andean zone and the Eastern Plains.[3] The Andean zone has a desert polar climate, with strong and cold winds and high solar radiation, with maximum temperature of 20 °C and minimum below 0 °C. The Sub-Andean zone features a very humid and rainy climate and the average temperature varies between 15 °C and 25 °C. The average temperature of the Eastern Plains is around 30 °C. [1,3]
Topography	Bolivia is a landlocked country with geographic zones that feature enormous variations in altitude.[3,6] The Andean zone is located in the west of the country and covers about 28 per cent of the national territory. It is a mountainous zone formed by the Occidental, the Oriental, Royal, the central Cordillera and the "Altiplano". The highest point is the Sahama peak at 6,542 metres, the average altitude along the Andean region is between 3,750 metres and 4,000 metres.[1,3,6] The Sub-Andean zone, commonly known as the "Yungas" and "Valles", are valleys of varying altitudes, with an average of 2,500 metres. The Eastern Plains, known as the "Llanos", cover the tropical savannahs, the Amazonian forest, agricultural lands and the desert region of "El Chaco", which has enormous biodiversity. It occupies almost two thirds of the national territory. The region has an average altitude of 400 metres and a minimum altitude of 90 metres at the Paraguay River.[3,6]
Rain pattern	Bolivia has a tropical climate with average precipitation of 640 mm per year. The rainy season is between mid-October to March.[9,12] Rain is much more pronounced in the Sub-Andean zone and the Eastern Plains. Precipitation patterns in these zones vary from 2,000 mm per year in the north to 600 mm per year in the south. Precipitation is highest in the valleys, reaching up to 6,000 mm per year.[3,12] In the Andean zone, particularly at the Altiplano, it rains much less. Precipitation can be as low as 200 mm per year, except in the area surrounding Titicaca Lake basin where precipitation can reach up to 1,000 mm per year.[3,12]
Hydrology	The most important rivers of Bolivia start in the Andes mountains and descend across the valleys into the eastern tropical lands. The three main watersheds and river systems are: 1) The Amazonian Basin which runs from the east to the west, constitute mainly of the Madre de Dios, Orthon, Abuná, Beni, Yata, Mamore and Iténez or Guaporé rivers. The Guaporé, the Mamoré, the Beni, and the Madre de Dios rivers cross the often-flooded northern savannah and tropical forests, all converging in the north-east to form the Madera River which flows into Brazil; 2) The Central or Lake Basin formed by the Titicaca and Poopó lakes, the Desaguadero River and large salt lakes Coipasa and Uyuni. Titicaca Lake is 222 km long and 113 km wide; with its surface at an altitude of 3,805 metres, it is the highest navigable lake in the world. The lake is drained to the south by the Desaguadero River, which empties into Poopó Lake; 3) The South or La Plata River basin composed mainly by the Paraguay, Pilcomayo and Bermejo rivers crossing the Chaco region to the south-east leaving Bolivia to form the border between Paraguay and Argentina.[3,6]

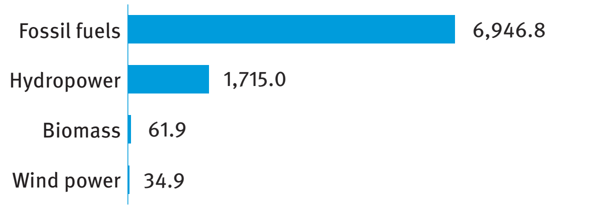
Electricity sector overview

The major share of Bolivia's electricity is from non-renewable thermal sources of natural gas combustion turbines, where the installed capacity of all the thermal sources is 1,314.6 MW (70.9 per cent) and the energy produced in 2016 was 6,946.8 GWh (79.3 per cent). This is followed by hydropower energy, with a total installed capacity of 483.2 MW (26.1 per cent) and energy produced of 1,715.0 GWh (19.6 per cent). There are other minor sources including wind (27 MW) and biomass (30 MW) representing 3.1 per cent of the total installed capacity and producing 34.9 GWh and 61.9 GWh, respectively, of the electricity demand for the national interconnected grid.[13] Figure 1 shows the annual electricity generation in Bolivia.

Until 2016, the total installed capacity of the national grid was 1,854.76 MW, with the maximum instantaneous power demand registered to be 1,433.6 MW and total demand reaching 8,377.8 GWh. Electricity demand has grown 5.4 per cent in relation to 2015.[13] There is no accurate data related to isolated networks, however it is estimated that demand for them is around 600 GWh (2014).[10,17] Access to electricity in

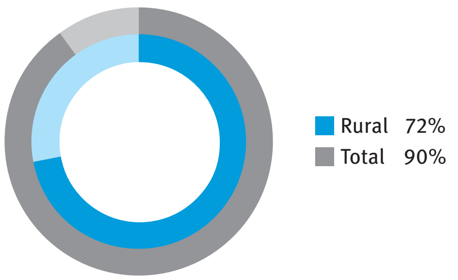
Bolivia is estimated to be at a rate of 90 per cent, where the urban coverage is 99 per cent and rural access is 72 per cent (Figure 2).[1]

Figure 1.
Annual electricity generation by source in Bolivia (GWh)



Source: Comité Nacional de Despacho de Carga [13]

Figure 2.
Electrification rate in Bolivia (%)



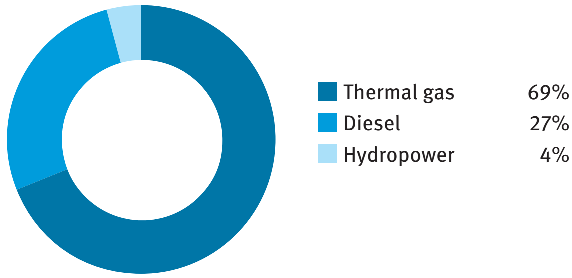
Source: CIA[1]

The electricity sector of Bolivia comprises the national grid, known as "Sistema Interconectado Nacional" (SIN), the wholesale market, the end consumers and several isolated networks.[13] Bolivia is politically divided into nine departments (states) – La Paz, Cochabamba, Santa Cruz, Pando, Beni, Chuquisaca, Oruro, Potosí and Tarija. The national grid extends across the departments of La Paz, Oruro, Potosí, Chuquisaca, Cochabamba, Santa Cruz, Beni and Tarija.[1,2,3] There are 4,466.1 km of transmission lines including 2,701.1 km at 230 kV, 1,645.9 km at 115 kV and 119.1 km at 69 kV to transport electricity to the distribution utilities along the national grid.[13]

In 2012 there were 38 operative and registered isolated networks, most of them located in the departments of Pando, Beni, Santa Cruz and Tarija. The installed capacity for these isolated grids in 2012 was 179.4 MW. The grids' share of energy sources was also mainly thermal – gas (75.6 MW, 69 per cent) and diesel (32.3 MW, 27 per cent) powered units that produced 345.5 GWh/year and 152.9 GWh/year, respectively. Small hydropower accounted for 8 MW (4 per cent) of the total installed capacity and produced 35.1 GWh.[14]

According to the energy sector authorities, annual electricity demand will reach 14,336 GWh by 2022 and will increase to more than 22,000 GWh by 2030, requiring a total installed capacity of 2,297 MW in 2022 and more than 3,500 MW in 2030. The potential increase in energy production for each energy source in 2022 is shown in Figure 4. Approximately 53 per cent of this future demand will be fulfilled by hydropower.[14]

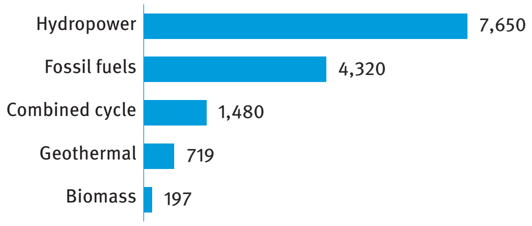
Figure 3.
Energy sources of isolated networks in Bolivia (%)



Source: Ministerio de Hidrocarburos y Energía[14]

Note: Data from 2012.

Figure 4.
Estimated energy demand in 2022 in Bolivia (GWh)



Source: Ministerio de Hidrocarburos y Energía[14]

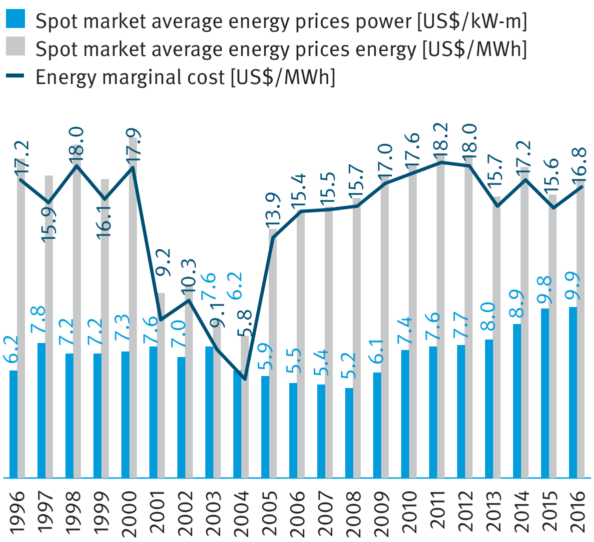
Both public and private companies participate in the electricity sector. The Government participates mainly through Empresa Nacional de Electricidad (ENDE) – Corporación, owning several generation, transmission and distribution utilities across the country. ENDE is responsible for planning the growth of the electrical market and developing energy projects.[13,17,18]

The Government authorities and institutions that regulate the Bolivian electricity sector are: the Ministry of Energy, the Vice-ministry of Electricity and Alternative Energy, the Vice-ministry of High Energy Technologies, the regulation and control authority Autoridad de Fiscalización y Control Social de Electricidad (AE), the interconnected system administration, control and operation entity Comité Nacional de Despacho de Carga (CNDC) and the Government's energy corporation Empresa Nacional de Electricidad (ENDE).[13,17,18]

Despite fossil fuels being the predominant energy source, electricity tariffs in Bolivia are amongst the lowest in South America. This is due to the subsidized gas and diesel prices for electricity production. The end users are classified into two groups: non-regulated and regulated consumers. If the demand of a single end user exceeds 1 MW then the consumer is classified into the non-regulated group. Those in the non-regulated group are allowed to participate in the spot market as well as to make power purchase agreements (PPA) which have been previously authorized by the competent authority. End users with a demand below 1 MW belong to the regulated group and their demand is attended to by the local electricity distribution utilities.[13,17,18] The energy transactions are held in the wholesale spot market administrated by the CNDC. The CNDC is also responsible for the operation, safety and optimization of the national grid.[13,17,18]

For the commercial transactions in the Interconnected National Grid, on the spot market, the electricity sales are paid by the sum of two figures – the energy produced and the power availability. The energy sales price is a function of the generation marginal cost. This represents the energy cost of the last unit required to generate the next kWh demanded by the system, affected by a factor that considers the losses at the node, where the energy is delivered to the grid. The power availability price is the calculated cost related to the estimated investment and the fixed operation cost required to supply the demand plus a reserve in the long term to guarantee the supply of the future energy demand.[13] In 2016, the average energy marginal cost in the spot market was 16.8 US$/MWh and the corresponding average energy sales price was 17.3 US$/MWh. The average power availability price was 9.9 US$/kW-month. Figure 5 shows the variation of energy and power availability prices in spot market since 1996.[13]

Figure 5.
Spot market marginal cost and sales prices (US$)



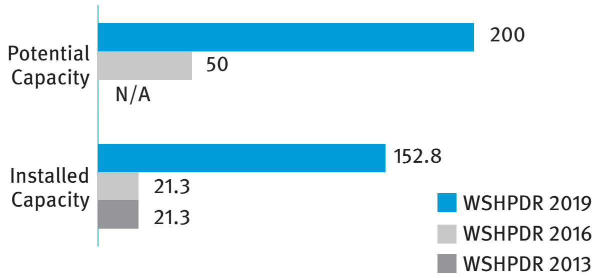
Source: Comité Nacional de Despacho de Carga[13]

The Government has plans to develop the electricity sector by increasing the country's installed capacity, which will be supplied mainly from hydropower schemes. The energy will also be exported to neighbouring countries. Bolivia has the potential to develop 39.9 GW of hydropower. The most suitable region is the Amazonian basin with a potential capacity of 34.2 GW, followed by the Plata River basin with 5.4 GW, and the Andean Basin (Altiplano) with 0.3 GW.[10,13,14]

Small hydropower sector overview

The definition of small hydropower in Bolivia is up to 5 MW, however for the purposes of this report, the standard definition of up to 10 MW is used. Approximately 7 per cent of the electricity produced to supply the national grid in the country comes from 33 small hydropower schemes (below 10 MW). These facilities belong to both private and public (ENDE) companies. The total available small hydropower capacity is 124.8 MW while total installed capacity is 152.8 MW (Figure 6) and the estimated energy production for 2016 was 628.7 GWh.[13]

Figure 6.
Small hydropower capacities 2013/2016/2019 in Bolivia (MW)



Source: Comité Nacional de Despacho de Carga,[13] *WSHPDR 2013*,[21] *WSHPDR 2016*[22]

Note: The comparison is between data from *WSHPDR 2013, WSHPDR 2016* and *WSHPDR 2019.*

In rural areas, there are many small hydropower plants to supply isolated networks such as small villages or industry (mines). Some of these schemes were constructed during the development of the mining industry back in the 19th century and many others were installed within the past 30 years to meet the demand of local communities. Most of the identified power plants are out of service or in poor condition and could be eligible for refurbishment. There are 52 identified existing plants in the regions of La Paz (Yungas), Oruro and Potosí with a total installed capacity of 28 MW, therefore the estimated total installed capacity of small hydropower is 152.8 MW (Figure 6).[5,8,13,15]

The Government's strategic plan includes the development of renewable hydropower projects considered to be up to 30 MW classified as follows:

- Micro: P< 500 kW;
- Small: 500 kW < P < 5 MW;
- Medium: 5 MW < P < 30 MW.[20]

The strategic plan includes small hydropower projects of approximately 30 MW for grid connection and another 20 MW for isolated networks, all of them in progress of identification. Such projects as well as other endeavours can be studied, developed and constructed by public or private investment and for connection to the national grid or to supply isolated networks.[20] The approximate 50 MW for small hydropower projects from the strategic plan, along with the installed capacity of 152.8 MW thus brings the potential of small hydropower up to approximately 200 MW.

The authorities are aware that the energy prices and other financial conditions in the country are insufficient to get a good rate of return for a small hydropower project investment or any other renewable source. Therefore, the Government is working to establish a financial policy in order to finance hydropower and other renewable projects by creating a fund that is allocated to the reduction of thermal production in either gas or diesel and to subsidize renewable energy sources.

The Government is also working on the structure and rules to finance small hydropower and other renewable energy technologies, such as by assigning incentives to the local (department) Government when the installed capacity is below 2 MW; and to the municipalities or to the indigenous authorities when the project is of an installed capacity less than 1 MW.[20]

Renewable energy policy

The Government has set the goal to change the energy mix, as of today dominated by gas units, to renewable energy sources, principally hydroelectric. An important reason to encourage hydroelectric projects is because of the country's enormous hydropower potential. This will also reduce the amount of natural gas used to meet the local demand. It can be exported instead to Brazil and Argentina for a price that is about seven times higher than the price established for the local market, which has been subsidized for energy production.[13,14,17]

In 2014, the Government published the new Investment Promotion Law, as well as Supreme Decree No. 2048 for renewable energy projects remuneration, both for the promotion of investments in the electricity sector, especially for hydropower, wind, geothermal and solar projects. Therefore, today the political scene is becoming more suitable and attractive for both foreign and local investments in the electricity sector.[20]

Renewable energy projects, including run-of-river hydropower schemes, will not be remunerated according to the actual electricity tariff system, which considers a combined payment for energy produced and the capacity of available power. These projects will be paid for by energy production as stated on the Supreme Decree No. 2048.[20]

The energy tariffs for new projects are not defined yet, nor are financial mechanisms. Regulations and investment frameworks are in the process of being implemented. Each project will have to negotiate and establish the energy price through a purchase agreement according to ENDE's requirements, the interests of the investor and AE's authorizations. Some benefits to small hydropoer projects may include:[20]

- Exemption of taxes for importing equipment and construction
- Subsidies coming from the Government's renewable energy fund
- Guaranteed price from a mid or long-term purchase agreement which ensures generation costs to be covered and an acceptable investment return rate
- Stable tributary conditions for 10 years
- From the beginning of the commercial operation date, being able to defer the aggregated value tax payment for five years
- Some other benefits may include the exception to pay the transmission and the grid administrator (CNDC) fees.

Barriers to small hydropower development

Bolivia is a country with potential for small hydropower development. There are many identified sites suitable for small hydropower facilities as well as existing plants in need of refurbishment.

The main challenges to consider for developing small hydropower projects in Bolivia are, but not limited to:

- Developing large hydropower schemes to export energy to neighbouring countries is the Government's priority, thus policies are geared towards this.
- Renewable energy development framework, rules and conditions have not been established yet.
- Low energy prices are not very attractive for private investments.
- Poor quality of hydrological, climate and other statistical data, especially for rural areas.
- Hard to establish a private company or develop a private hydropower project price wise and competitively as well as for it to be socially accepted.
- Having to deal with the social situation in Bolivia. Roadblocks and protests can interfere with the project development, construction and further operations.
- Projects can be cancelled due to a lack of social acceptance.
- Government procedures, authorizations and paperwork can take a long time. The bureaucracy in Bolivia is complicated, the procedures and paperwork to comply with the requirements often take longer than expected. Previsions always have to be taken in order to comply with deadlines related to legal paperwork.

References

1. CIA. World Fact Book. *Central Intelligence Agency,* 2018. Available from https://www.cia.gov/library/publications/the-world-factbook/geos/bl.html. Accessed 20 February 2018.
2. worldatlas.com. Bolivia Geography. *World Atlas*. Available from http://www.worldatlas.com/webimage/countrys/samerica/bolivia/boland.htm#page. Accessed 20 February 2018.
3. INE. Aspectos Geográficos. *Instituto Nacional de Estadística* (INE). Available from https://www.ine.gob.bo/index.php/bolivia/aspectos-geograficos. Accessed 19 February 2018.
4. INE. Resultados del Censo Nacional 2012. *Instituto Nacional de Estadística* (INE). Available from http://censosbolivia.ine.gob.bo/webine/article/según-datos-del-censo-2012-673-de-la-población-del-paper centC3per centADs-habita-en-áreas-urbanas-y-327-en. Accessed February 19, 2018.
5. Romao, Cleber. Inventario de micro, mini y pequeñas centrales en Bolivia. *Fundación SOLYDES* (2017) Available from http://www.unicef.org/bolivia/resources_2334.htm
6. Advameg, Inc. Bolivia Topography. *Nations Encyclopedia*. Available from http://www.nationsencyclopedia.com/Americas/Bolivia-TOPOGRAPHY.html" \l "ixzz3hc4mg6HF. Accessed 22 February 2018.
7. INE.Censos Bolivia (n.d). *Instituto Nacional de Estadística* (INE). Available from http://censosbolivia.ine.gob.bo/webine/article/según-datos-del-censo-2012-673-de-la-población-del-paper centC3per centADs-habita-en-áreas-urbanas-y-327-en. Accessed 22 February 2018.
8. Instituto Nacional de Estadística (INE). Servicios Básicos, Censos 1992, 2001 y 2012. *INE.* Available from https://www.ine.gob.bo/index.php/educacion-5/vivienda-y-servicios-basicos-3/

censos-1992-2001-y-2012. Accessed 20 February 2018.
9. Servicio Nacional de Meteorología e Hidrología de Bolivia. *SENAMHI*. Available from http://www.senamhi.gob.bo. Accessed 5 February 2018.
10. Ministerio de Energias. Memoria Anual 2014. *Comité Nacional de Despacho de Carga (CNDC).* Available from http://www.cndc.bo/home/index.php. Accessed February 15, 2018.
11. Instituto Geográfico Militar de Bolivia (IGM). Mapas de Bolivia. *igmbolivia*. Available from http://www.igmbolivia.gob.bo/download.php. Accessed 7 February 2018.
12. AgroBolivia (n.d). Cambio Climático en Bolivia. *agrobolivia.* Available from https://agrobolivia.files.wordpress.com/2011/03/docppver3.pdf. Accessed 22 February2018.
13. Ministerio de Energias. Memoria Anual 2016. *Comité Nacional de Despacho de Carga (CNDC)*. Available from http://www.cndc.bo/home/index.php. Accessed 15 February 2018.
14. Ministerio de Hidrocarburos y Energía. *Plan Eléctrico del Estado Plurinacional de Bolivia 2025* (2014).
15. Orellana, Renán and Nelson Bellot. Sistemas Eléctricos Aislados y Consumo de Diesel en Bolivia (2011). Available from http://idbdocs.iadb.org/WSDocs/getdocument.aspx?DocNum=37860239. Accessed 18 February 2018.
16. IVC. Bolivia lanza la mayor inversión hidroeléctrica de la region. *revistapetroquimica* (January, 2017). Available from https://revistapetroquimica.com/bolivia-lanza-la-mayor-inversion-hidroelectrica-la-region/. Accessed 18 February 2018.
17. Empresa Nacional de Electricidad (ENDE). Memoria Anual 2013. *ende.bo*. Available from http://www.ende.bo/memorias. Accessed 5 February 2018.
18. Autoridad de Fiscalización y Control Social de Electricidad (AE). Available from http://www.ae.gob.bo/aewebmobile/main. Accessed 5 February 2018.
19. ENERGÍABolivia. Potencial y Aprovechamiento de la Hidroenergía en Bolivia. *Energía Bolivia*. Available from http://www.energiabolivia.com/index.php?option=com_content&view=article&id=3455:potencial-y-aprovechamiento-de-la-hidroenergia-en-bolivia&catid=68&Itemid=198. Accessed 22 February 2018.
20. Ministerio de Hidrocarburos y Energía. Presentación: Introducción a las energías alternativas. *Seminario de Energías Renovables*(2014).
21. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
22. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.

2.3.3 Brazil

Geraldo Lúcio Tiago Filho, Camila Galhardo and Luiza Fortes Miranda, National Reference Center for Small Hydropower Plants

Key facts

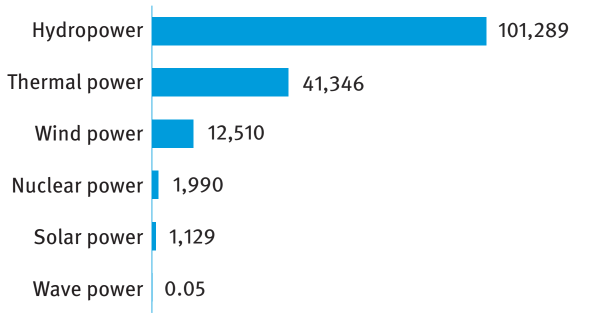
Population	207,660,929[1]
Area	8,515,692 km[2]
Climate	The climate is mainly tropical, but temperate in the south and equatorial in the north. In the Amazonian region, average temperatures reach above 28 °C. The north-eastern region is humid, tropical and semi-arid with average temperatures between 20 °C and 28 °C. In the south-east, average annual temperatures vary between 19 °C and 24 °C. However, in the south, the coldest regions have average temperatures below 20 °C. During the winter month of June, average temperature varies between 11 °C and 18 °C.[2]
Topography	The terrain is mostly flat, with approximately 93 per cent of the territory lying at altitudes of below 900 metres. In the north lie the Amazon lowlands, which constitute the world's largest tropical rain forest. In the northernmost part of the country lie the Guiana Highlands, where the highest peak of Brazil, Pico da Neblina at 3,014 metres, is located. The Brazilian Highlands, ranging in elevation from 300 to 910 metres, cover most of the central, eastern and southern parts of the country. The coastline is mainly represented by the Great Escarpment, which in the south-east is surmounted by mountain ranges reaching up to 2,400 metres.[3]
Rain pattern	In the Amazonian region, annual precipitation is 2,300 mm on average, but there are locations where precipitation exceeds 5,000 mm/year. The north-eastern region presents annual precipitation of between 300 mm and 2,000 mm. In the mid-west, precipitation is well spread and is about 1,500 mm/year. In the south-east, rainfall ranges between annual averages of 1,250 mm and 2,000 mm, exceeding 4,500 mm in Bertioga, on the central coast of São Paulo state.[2]
Hydrology	The eight main river basins all drain into the Atlantic Ocean. The Amazon and the Tocantins-Araguaia river basins account for over half of the drainage in the country. The Amazon River and its tributaries account for one-fifth of the world's freshwater. The Amazon River flows for more than 3,000 km within Brazil. Its major tributaries include the Javari, Juruá, Purus, Madeira, Tapajós, Xingu and the Tocantins on the southern side, and the Branco, Japurá, Jari and the Negro on the northern side.[2,4]

Electricity sector overview

The total installed capacity of Brazil in March 2018 was 158.26 GW, with hydropower accounting for 64 per cent, thermal power 26 per cent, wind power 8 per cent, nuclear and solar power for approximately 1 per cent each and wind power for less than 0.001 per cent (Figure 1).[7]

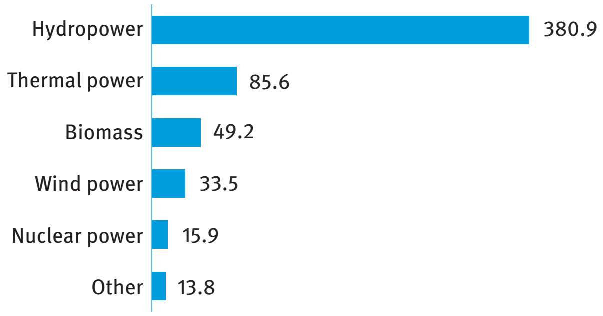
In 2016, the electricity sector of Brazil generated a total of 579 TWh of electricity.[8] Hydropower contributed 66 per cent, thermal power 15 per cent, biomass 8 per cent, wind power 6 per cent, nuclear power 3 per cent and other sources 2 per cent (Figure 2).[8]

Figure 1.
Installed electricity capacity by source in Brazil (MW)



Source: ANEEL[7]

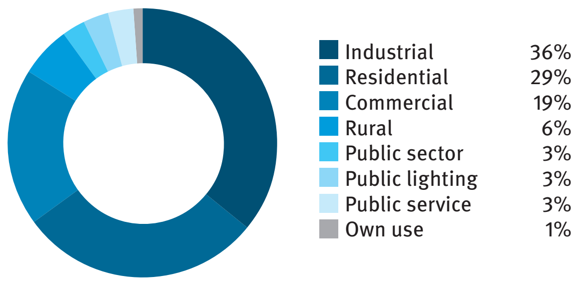
Figure 2.
Annual electricity generation by source in Brazil (TWh)



Source: EPE[8]

In 2016, the electrification rate in Brazil reached 100 per cent, both in urban and rural areas.[6] The total electricity consumption in 2016 was at 461 TWh (0.9 per cent less than in 2015). Of this, 36 per cent was consumed by the industrial sector, followed by the residential (29 per cent) and commercial (19 per cent) sectors (Figure 3).[8]

Figure 3.
Electricity consumption by sector in Brazil (%)



Source: EPE[8]

The first hydropower plants were built in Brazil at the end of the 19th century, in order to meet the energy needs of the mining, textile, and agricultural products processing industries. Until 1950, most of the hydropower plants in the country were small and predominantly located at waterfalls, allowing the direct use of hydropower. Later on, in line with the centralized energy planning policies, many federal and state hydropower companies were created. This also induced the implementation of interconnected systems composed of large hydropower plants. Hydropower has been seen as a clean and efficient way to expand the Brazilian energy capacity. Additionally, because of their features, hydropower projects are more suitable for an interconnected energy system.

The process of privatization and unbundling of the electricity sector was started in 1994. The Government intended to change the model from a state-owned monopoly to private competition.[9] However, due to the lack of investment caused by the 2000 drought, which culminated in a severe crisis of the Brazilian electricity sector in 2001, the plan had to be postponed. The new regulatory framework, established between 2003 and 2004, made investment in renewable energy sources feasible and laid down the foundation for the participation of public and private actors.[9] The energy market was standardized and became a hybrid comprising a regulated part and a part of wholesale competitive trade. A recent public consultation (Public Consultation No. 33), which took place in July 2017, showed that most of the agents involved in the electricity sector would prefer the sector to be as free as possible.[10]

Table 1.
Power plants in Brazil

Type	*Number*	*Installed capacity (MW)*
Hydropower > 30 MW	218	95,619
Hydropower 5 MW – 30 MW	429	5,043
Hydropower <5 MW	669	627
Thermal power	3,001	41,346
Wind power	510	12,510
Nuclear power	2	1,990
Solar power	89	1,129
Wave power	1	0.05
Total	**4,919**	**158,264.05**

Source: ANEEL[7]

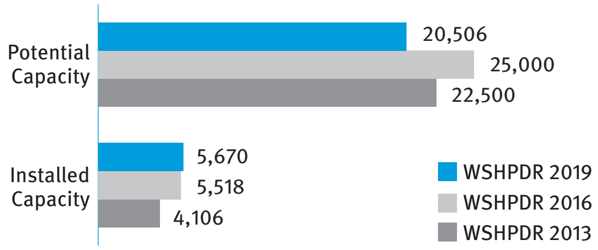
The electricity sector of Brazil is regulated through policies formulated by the Ministry of Mines and Energy (Ministério de Minas e Energia, MME) with the assistance of the National Council of Energy Policy (Conselho Nacional de Política Energética, CNPE) and the National Congress. The National Agency of Electric Energy (Agência Nacional de Energia Elétrica - ANEEL) is responsible for analysing electricity sector resolutions to ensure the welfare of the society and the economy. ANEEL acts as a regulatory agency, while the National Energy System Operator (Operador Nacional do Sistema, ONS) is responsible for coordinating and supervising the centralized operation of the Brazilian interconnected energy system. The Committee for Monitoring the Electric Sector, also associated with the MME, was created to pertinently monitor and evaluate the continuity and security of the power supply across the country. There are also other players in the sector such as the Power Research Company (Empresa de Pesquisa Energética, EPE), also associated with the MME, whose role is to perform the necessary studies for planning the expansion of the electricity system. Another agent is the Power Commercialization Chamber (Câmara de Comercialização de Energia Elétrica, CCEE), which handles negotiations on energy in the free market.

Consumer tariffs are regulated by ANEEL, while in the free market prices are established through contracts. Electricity prices in Brazil vary according to the distribution company (i.e., the geographic region) and the end-user (residential, industrial, commercial, public service, etc.). Taking the average rate applied in Brazil in 2016, the price rose by approximately 6 per cent compared to 2015 and reached 0.419 BRL/kWh (0.11 US$/kWh).[8]

Small hydropower sector overview

As of March 2018, there were 1,098 small hydropower plants up to 30 MW in operation in Brazil with a combined installed capacity of 5,670 MW.[7] The potential is estimated at 20,506 MW, including 7,021 MW of potential available in the short term and 1,856 MW of potential already suitable for auctions.[16] Compared to the *World Small Hydropower Development Report (WSHPDR) 2016*, installed capacity increased by almost 3 per cent due to the introduction of new plants, whereas potential capacity decreased by approximately 18 per cent as a result of a more accurate estimate (Figure 4).

Figure 4.
Small hydropower capacities 2013/2016/2019 in Brazil (MW)



Source: ANEEL,[7] ABRAGEL,[16] *WSHPDR 2013*,[17] *WSHPDR 2016*[18]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

Note: This report uses the definition of SHP as hydropower plants with capacity up to 30 MW.

The definition of small hydropower (SHP) in Brazil has evolved over time. The first definition was set in 1982 and restricted SHP to 10 MW. However, this definition does not fit the present reality. As a result, ANEEL Resolution No. 673 of 2015 established a new definition of SHP as hydropower plants used for self-generation or independent electricity generation and with an installed capacity above 3 MW and below 30 MW.[11] Furthermore, the maximum reservoir area was limited to 13 km^2 (excluding the regular riverbed). In case of a reservoir area exceeding 13 km^2, the plant is still considered an SHP plant if it is at least a weekly regularized reservoir or if it has proven purposes other than electricity generation. Resolution No. 673 also states that hydropower projects below 3 MW have simpler implementation rules, only requiring notifying ANEEL; although they are also required to follow the environmental and other state requirements, which serves as an important incentive for SHP plants below 3 MW.[12]

Law No. 13.360 of 17 November 2016 established a new definition of SHP from 5 MW up to 30 MW.[12] However, plants from 3 MW to 5 MW that were commissioned before the new law are still classified as small hydropower, therefore, the actual installed capacity of all hydropower plants considered as SHP exceeds the capacity of SHP according to the new definition. Furthermore, the definition of reservoir area of SHP plants as per ANEEL Resolution No. 673 is still being used. The Normative Resolution of ANEEL No. 765 of 2017 establishes the procedures for obtaining a grant for hydropower projects between 5 MW and 50 MW that do not have all the characteristics of small hydropower plants listed above.[13] Finally, Normative Resolution No. 482 of 2012 regulating distributed generation, was updated by Normative Resolution No. 786 of 2017, which changed the maximum size limit for plants for distributed generation from 3 MW to 5 MW.[14,15] This means that more SHP plants can be considered as distributed generation plants and can enjoy the regulations for this kind of generation. Hydropower plants up to 5 MW (for distributed generation) are further classified as micro if their capacity is up to 75 kW and as mini if above 75 kW and below 5 MW.[14,15]

According to The Brazilian Decennial Plan for Energy Expansion 2026 (Plano Decenal de Expansão de Energia 2026, PDE 2026), the Brazilian Government predicts that the installed capacity of SHP will reach 6,658 MW (3.78 per cent of total) in 2020 and 7,858 MW (3.80 per cent) in 2025. This shows that the relative share of SHP in the country's energy mix is not expected to grow substantially. For comparison, the share of wind power is expected to rise by 10.0 per cent in 2020 to 12.9 per cent in 2025, which shows that the Governmental incentives, such as tax exemptions, are expected to stay in place and to have positive results on the development of these sources.[19]

SHP represents a renewable energy alternative which brings several benefits to the Brazilian energy sector, such as synergy with other sources, flexibility of operation and storage. SHP also brings social and economic development to the region where the plant is installed. In most cases, SHP entrepreneurs must invest in some improvements for the region as a mitigation measure for the environmental impacts caused by the project. Although the possibility of negative consequences of SHP development is minimized due to the above measures, the Brazilian society seems to have transferred, in a general manner, the disadvantages of large hydropower plants onto SHP. This certainly has a significant impact on the public perception of SHP and, hence, the prospects of SHP development.

Renewable energy policy

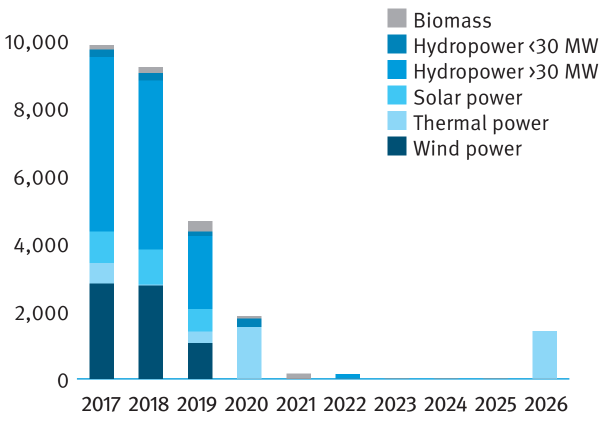
The Incentive Programme for Alternative Energy Sources (Programa de Incentivo às Fontes Alternativas, PROINFA) launched in 2002 was the first important programme to promote renewable energy sources in Brazil. Its primary focus was on biomass, wind power and SHP. This programme is similar to the feed-in tariff scheme, but is applicable to large-scale projects. Although PROINFA contributed to the diversification of the country's energy mix and the expansion of the share of some renewable energy sources, the prices of electricity generated from renewable energy sources remained high. The second mechanism to promote renewable energy sources was power auctions. Specific auctions were offered for a restricted group of energy sources and mainly served as another incentive for large-scale renewable energy projects. Besides, the net metering model was chosen for on-site generation, benefiting mainly the solar photovoltaic market.

As a result of these incentives, lately SHP has been losing its share of the energy mix to other renewable energy sources. The Brazilian Decennial Plan for Energy Expansion 2026 shows that SHP projects contracted as of 2016 accounted for only 2.4 per cent of the total power generation capacity to be commissioned in 2018 and 2.6 per cent in 2019 (Figure 5). At the same time, wind power accounted for 29.9 per cent and 22.5 per cent of the total contracted expansion in 2018 and 2019, respectively, while solar photovoltaic power for 11.2 per cent and 14.4 per cent, respectively.[19] Although these data demonstrate that currently photovoltaic and wind power are growing faster than SHP, the PDE 2026 also indicates that there is a wide range of SHP projects not yet developed.

In the last few years, wind power projects have been showing lower prices in the auctions, and the wind power sector has been growing noticeably faster than SHP. The construction and operation costs of SHP in Brazil have been higher than those of other energy sources. Besides, SHP electromechanical equipment is expensive and does not receive tax exemptions as wind power and solar power equipment (e.g. on the Tax on Circulation of Goods and Services).

Furthermore, the development of SHP is hindered by the environmental licensing process. According to the resolution CONAMA 01/86, power plants above 10 MW, regardless of the energy source, are considered as potential sources of negative environmental impact.[20] Projects of SHP plants between 10 MW and 30 MW, thus, require an Environmental Impact Assessment (Estudo de Impacto Ambiental, EIA) and Environmental Impact Report (Relatório de Impacto Ambiental, RIMA).

Figure 5.
Contracted capacity expansion as of 2016 (MW)



Source: EPE [19]

However, for SHP projects between 3 MW and 10 MW, it is allowed to make a Simplified Environmental Report (Relatório Ambiental Simplificado, RAS). Hydropower plants below 3 MW have to go through a less rigorous process of environmental licensing. On the other hand, SHP projects of such a small size are expensive and unattractive to investors. Conversely, wind power and photovoltaic solar projects enjoy a simplified and faster environmental licensing process, which combined with the other policies, benefits these two renewable sources to the detriment of SHP.

Nonetheless, there are instruments of support for small hydropower in place as well. Key ones include:

- Free access to the transmission and distribution networks;
- Discount of at least 50 per cent on the tariffs for using the transmission and distribution systems;
- Exemption from the payment of the financial compensation for inundation;
- Incentive for distributed generation (plants up to 5 MW);
- Energy Reallocation Mechanism (MRE), in which small hydropower plants can participate optionally.

Barriers to small hydropower development

SHP projects are currently in a disadvantaged position in relation to other renewable energy sources, mainly wind power, which receives more incentives. The key barriers to SHP development include:

- Limited incentives compared to other renewable energy sources, which makes SHP projects less competitive;
- Strict requirements for environmental licensing process for plants between 10 MW and 30 MW;
- High cost of constructing and operating SHP plants;
- The costs of civil construction and electromechanical equipment are elevated and are not covered by tax exemptions;
- A generally negative public perception of all hydropower.

References

1. Instituto Brasileiro de Geografia e Estatística (IBGE) (2017). *Estimativas de População*. Available from https://www.ibge.gov.br/estatisticas-novoportal/sociais/populacao/9103-estimativas-de-populacao.html
2. Cavalcanti, I.F.A., et al. (2009). Tempo e Clima no Brasil 2009. São Paulo: Oficina de Textos. pp. 464.
3. Encyclopaedia Britannica (2018). Brazil. Available from https://www.britannica.com/place/Brazil#ref25059
4. Instituto Brasileiro de Geografia e Estatítica (2002). Mapa de clima do Brasil. Rio de Janeiro.
5. Tolmasquim, M. T. (2016). *Energia renovável: hidráulica, biomassa, eólica, solar, oceânica*. Rio de Janeiro. Available from http://www.epe.gov.br/Documents/Forms/AllItems.aspx
6. World Bank (2016). *Access to Electricity by Country*. Available from https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?view=chart
7. Agência Nacional de Energia Elétrica (ANEEL) (2018). *Capacidade de Geração do Brasil*. Available from http://www2.aneel.gov.br/aplicacoes/capacidadebrasil/capacidadebrasil.cfm
8. Empresa de Pesquisa Energética (EPE) (2017). *Anuário Estatístico de Energia Elétrica*. Available from http://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/anuario-estatistico-de-energia-eletrica
9. Silva, B. G. (2011). Evolução do setor elétrico brasileiro no contexto econômico nacional: uma análise histórica e econométrica de longo prazo. Dissertação (mestrado em Ciências) – programa de Pós-Graduação em Energia da Universidade de São Paulo. P 162. Available from http://www.

teses.usp.br/teses/disponiveis/86/86131/tde-12032012-091848/pt-br.php
10. Empresa de Pesquisa Energética (EPE) (2017). *Processamento de contribuições à Consulta Pública 33/2017*. Available from http://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-232/topico-353/Nota%20T%C3%A9cnica%20EPE-PR-003-2017.pdf
11. Agência Nacional de Energia Elétrica (ANEEL) (2015). *Resolução Normativa n. 673 de 4 de Agosto de 2015*. Available from http://www2.aneel.gov.br/cedoc/ren2015673.pdf
12. Government of Brazil (2016). Lei n. 13.360 de 17 de Novembro de 2016. Available from http://www.planalto.gov.br/ccivil_03/_ato2015-2018/2016/lei/L13360.htm
13. Agência Nacional de Energia Elétrica (ANEEL) (2017). *Resolução Normativa n. 765 de 25 de abril de 2017*. Available from http://www2.aneel.gov.br/cedoc/ren2017765.pdf
14. Agência Nacional de Energia Elétrica (ANEEL) (2012). *Resolução Normativa n. 482 de 17 de abril de 2012*. Available from http://www2.aneel.gov.br/cedoc/ren2012482.pdf
15. Agência Nacional de Energia Elétrica (ANEEL) (2015). *Resolução Normativa n. 786 de 17 de outubro de 2017*. Available from http://www2.aneel.gov.br/cedoc/ren2017786.pdf
16. Associação Brasileira de Geração de Energia Limpa (ABRAGEL) (2017). Desafios para Expansão da Geração. Seminário Desafios da Geração de Energia Elétrica no Brasil, ANEEL, 19 June 2018. Available from http://www.aneel.gov.br/eventos/seminario-desafios-da-geracao-de-energia-eletrica-no-brasil
17. LIU, H., Masera, D. and Esser, L., eds. (2013). World Small Hydropower Development Report 2013, United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
18. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
19. Empresa de Pesquisa Energética (EPE) (2017). *Plano Decenal de Expansão de Energia (PDE) 2026*. Available from http://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/Plano-Decenal-de-Expansao-de-Energia-2026
20. Government of Brazil (1986). *Resolução CONAMA n. 001 de 23 de Janeiro de 1986*. Available from http://www.mma.gov.br/port/conama/res/res86/res0186.html

2.3.4 Chile

Patrick Furrer, Leonardo Aburto and Jorge Saavedra, Pöyry (Chile) Ltda.

Key facts

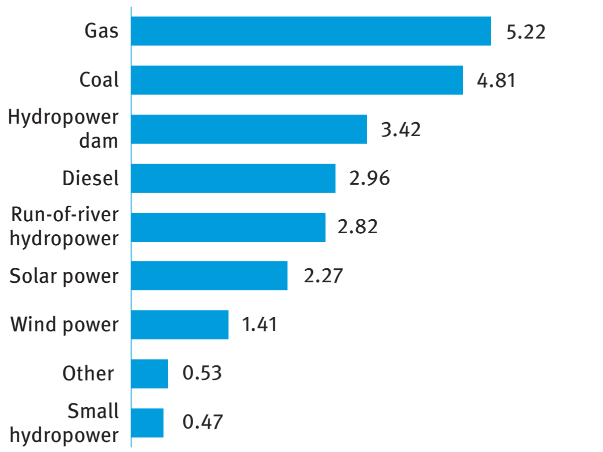
Population	17,574,003[1]
Area	756,100 km² (continental territory), 2,006,096 km² (continental, Antarctic and insular) [2]
Climate	Chile has a variety of climates: desert, Mediterranean steppe, warm rainy, temperate rainy, maritime rainy, cold steppe, tundra and polar (from north to south). In the Andes, highland climate prevails and on its high peaks, icy weather. Rapa Nui Island (Easter Island) has a subtropical climate with oceanic influence characteristics.[2]
Topography	Continental Chile is characterized as mountainous, with no more than 20 per cent of flat surface. The three main features of the relief of continental Chile are the Andes Mountains to the east, the coastal range to the west and the intermediate depression between the two mountain ranges. Between continental and southern Chile, there is a submerged mountain range whose highest peaks emerge forming islands, finally reaching the north-eastern tip of the Antarctic peninsula. Rapa Nui presents a relief plains and volcanoes.[2]
Rain pattern	Rainfall varies in amount and distribution across the territory. It increases while moving south. In far north, the average annual rainfall is less than 1 mm, while at the southern tip it can reach 5,000 mm or more.[2]
Hydrology	As a result of the relief and the narrowness of the territory, Chile's rivers are short, with steep slopes and low flow torrential that are unsuitable for navigation. They do however have great hydroelectric potential. The northern rivers are fed by snow thawing, the central ones have a mixed feeding, the southern ones are fed by rainfall and the austral ones have mixed regimes, fed by rain and thawing glaciers.[2]

Electricity sector overview

The total installed generating capacity in October 2018 was 23.9 GW (Figures 1 and 2), of which 99.9 per cent corresponded to National Electrical System (SEN).[3] Hydropower is the most important source of electricity in Chile, it takes 28 per cent (6.7 GW) from the total. The total electricity generated in 2017 was 74,647 GWh.[4]

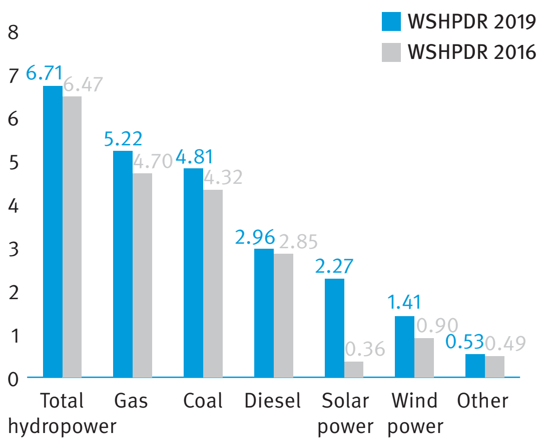
In the 1970´s the privatization and segmentation of the Chilean Electricity Market began. Firstly, the distribution segment (originally owned by the Chilean National Electrical Company ENDESA). Secondly, generation and transmission segments were privatized and afterwards separated in the mid 1990´s.

Figure 1.
Installed electricity capacity by source in Chile (GW)



Source: National Commission of Energy [3]

Figure 2.
Comparison of installed electricity capacity in Chile between *WSHPDR 2016* and *WSHPDR 2019* (GW)



Source: National Commission of Energy, [3] *WSHPDR 2016* [26]

Generation, transmission and distribution are unbundled horizontally. The sectors are, however, integrated vertically. Electricity system prices follow a marginalistic approach. Until 2005, the generation segment was dominated by three national companies, ENDESA Chile (today ENEL), AES Gener (former GENER) and Colbún. However, this has changed substantially with the appearance of other competitors (medium and small sized players). Nowadays there are more than 100 generation companies.

The largest electrical system is the National Electrical System (SEN), which is the interconnection of the previous North Interconnected System (SING) and the Central Interconnected System (SIC). The SEN serves approximately 98 per cent of the population. Other smaller networks are the Aysén System (SEA), Los Lagos generating unit and Magallanes System (SEM).

The average sale price of electricity (average node price in SEN) in July 2018 was 59,114 CLP/kWh (0.09 US$/kWh).[5] This value does not consider the costs of distribution or the charge for the use of the national transmission system.

The transmission system can transport electricity from generating plants located throughout the country to distribution companies' sub-stations and industrial consumers. The voltage levels in lines are between 23 kV and 500 kV, at a nominal frequency of 50 Hz. Transmission is dominated by four major historical players – TRANSELEC, ENGIE (Suez, E-CL), TRANSNET (CGE), ENEL (Chilectra) and after the construction of the 500 kV system, INTERCHILE.

The distribution system, consisting of lines, substations and equipment is established in two voltage ranges:

- Medium voltage (Line-Line): 2, 4, 3.3, 4.16, 6.6, 12, 13.2, 13.8, 15 and 23 kV;
- Low voltage (Line-Line): 380, 480, 660 V;
- Low voltage (Line-Neutral): 220, 277, 380 V.[6]

On the other hand, the distribution system is principally in the hands of four companies – ENEL (Chilectra), CGE, Chilquinta and SAESA.

For energy consumers, Chilean regulatory market defines two types of clients:

- Free customers (non-regulated clients): they have the capacity to negotiate energy supply contracts with distributors or directly with generators under a Power Purchase Agreement (PPA). Installed capacity of these users is greater than 5 MW. Typically, these clients are industrial or mining companies.
- Regulated clients: The Law establishes that they are subject to price regulation (calculated on the basis of a model distribution company operating efficiently). These users have installed capacity less than 5 MW.[7]

Customers with installed capacity between 500 kW and 5 MW can choose to be regulated customers or free customers.

In Chile, as established by the General Services Law, the main bodies involved in regulating the electricity market are:[7]

- Ministry of Energy: The public agency responsible for developing and coordinating the plans. Policies and standards for the proper functioning and development of the energy industry, ensuring compliance and advising the Government on all matters related to energy;[8]
- National Commission Energy is a public and decentralized body, with its own assets and full capacity to acquire and exercise rights and obligations. Its functions are analysing prices, tariffs and technical standards to which energy production, generation, transmission and distribution companies must adhere, in order to have a sufficient, safe and quality service, compatible with the most economical operation.[8]
- Electricity and Fuel Superintendence (SEC) is the public agency responsible for overseeing the energy market, in order to have safe and quality products and services. Furthermore, it supervises compliance with electrical regulations in Chile.[9]
- National Electrical Coordinator (CEN) is an independent body responsible for preserving the security of the service in the electrical system, guaranteeing the most economical operation of all system installations and planning the development of the transmission system. Additionally, CEN adopts the pertinent measures to monitor the chain of payments of the economic transfers subject to their coordination, guaranteeing their continuity.[10]
- Panel of experts is a body created by law, with limited competence, made up of professional experts, whose function is to pronounce by means of rulings with binding effect on those discrepancies that occur in relation to the matters that are expressly indicated in the General Law of Electrical Services (studies, tariffs, plans, etc.), and in other laws on energy matters.[11]
- Ministry of Environment is the body granting the approval of the environmental impact studies of the projects in the sector.[12]
- Municipalities are in charge of issuing permits for the use of public assets.

Small hydropower sector overview

Chilean Law 20.257 defines a small hydropower plant (SHP) as one with a maximum installed capacity below 20 MW.[13] SHP is considered a form of Non-Conventional Renewable Energy (ERNC). The Renewable Energy and Energy Efficiency Programme of the Ministry of Energy classifies hydropower into micro-, mini- and small hydropower according to installed capacity (Table 1).

The available installed capacity of SHP up to 20 MW as of August 2018 was 488 MW (Figure 3). In comparison to data from the *World Small Hydropower Development Report (WSHPDR)* 2016, installed capacity has increased while potential has stayed the same. The decrease in installed capacity between the *WSHPDR 2013* and *2016* was due to different methods of analysis rather than an actual decrease (Figure 3).

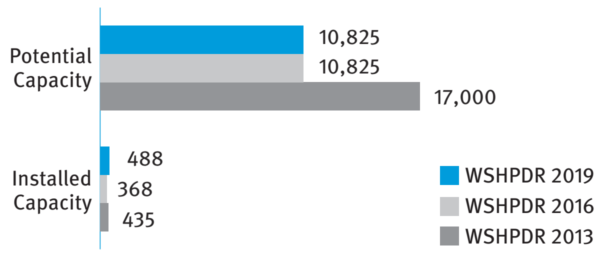
Additionally, in 2018 there were 46 MW SHP plants under construction and 824 MW of plants with an Environmental Qualification Resolution (RCA), meaning that they have permission to start SHP construction.[15] For SHP up to 10 MW, the total installed capacity was estimated at 236 MW and potential at 2,113 MW (Figure 4).[3,18]

Table 1.
Definition of small hydropower in Chile

Hydropower type	*Installed capacity*
Micro-hydropower	5 kW – 100 kW
Mini-hydropower	100 kW – 1 MW
Small hydropower	1 MW – 20 MW

Source: Ministry of Energy [14]

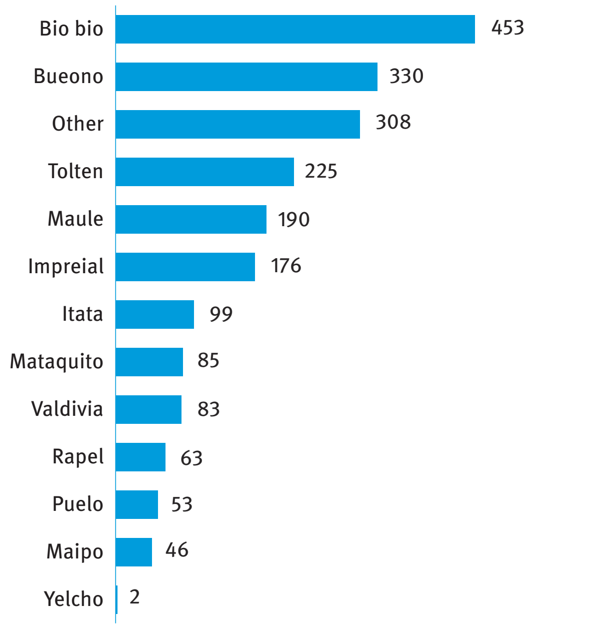
Figure 3.
Small hydropower capacities 2013/2016/2019 in Chile (MW)



Source: *WSHPDR 2016*,[26] *WSHPDR 2013*,[27] National Commission of Energy[3]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*

Figure 4.
Estimated potential capacity for small hydropower up to 10 MW by river in Chile (MW)



Source: Ministry of Energy [18]

The increase in the installed capacity of SHP was mainly due to regulatory changes in Decree 244 (which regulates small power plants). It has simplified the processing of projects less than 9 MW connected to the PMGD distribution network. Particularly for projects under 1.5 MW that has no significant impact on the grid (INS). The INS projects allow avoiding some electrical studies and steps to follow in the connection, which avoids important costs in the processing of the project.[15]

The estimated SHP potential up to 20 MW, including Maipo and Yelcho Rivers, is equivalent to 10,825 MW, the most promising being the Biobio River (2,453 MW), Yelcho River (1,376 MW) and Maule River (990 MW). This corresponds to a potential of a technical nature, which considers the Rights of Use of Non-Consumptive Water for installed power greater than 0.1 MW and plant factors greater than 0.5. This does not consider the potential in the southern area of the country (Aysen region) due to environmental restrictions.[18]

An additional potential associated with hydropower reservoirs used for irrigation works has been studied in 2007 for Rights of Use of Consumptive Water, and is estimated at 866 MW. The 558 MW correspond to plants that produce less than 20 MW and flows above 4 m^3/sec[19], which increases the total estimated SHP potential, including the natural streams and in irrigation works up to 11,383 MW.

Legislation on small hydropower

The Ministry of Economy's decree 244, regulates the mini and small hydropower as is indicated in the Table 2.[20] All these categories belong to the general definition of renewable non-conventional energy generators (RNCE) such as geothermal, wind, solar, biomass, co-generation and SHP.

Table 2.
The general definition of renewable non-conventional energy generators (RNCE)

Acronym in Spanish	*Classification*	*Meaning*
PMGD	small distributed generation plant	Plants whose generation is less than or equal to 9 MW, connected to the facilities of a distribution company
PMG	small generation plant	Plants whose generation is less than or equal to 9 MW, connected to the facilities of a transmission system
MGNC	non-conventional generation plant	Non-conventional renewable plants of generation whose capacity is less than 20 MW, The MGNC category is not exclusive with the above categories indicated.

Source: Ministry of Economy, Development and Reconstruction[20]

Law 19.940 includes the fee for small RNCE access to the transmission system and regulates the cost for small distributed RNCE to distribution systems. Law 20.018 requires energy generators to provide at least 5 per cent of their energy through sustainable means, or to purchase the equivalent from renewable sources. That percentage is set to rise to 10 per cent by 2024.

Currently, a comprehensive amendment of the Chilean Water Code is under discussion in the National Congress.[21] The amendment project aims to modify the concept of water rights in order to limit its exercise, make them temporary (20 or 30 years, with the possibility of renewal), limit the exercise of some water rights on scarcity situations, establish a "use it or lose it" clause, facilitate intervention of hydrological areas by the Government, and reform the non-use fee payment.

In 2016, the environmental evaluation services published a methodological manual for the calculation of the ecological flow. This is now used to define an independent ecological flow that prevails over the water right ecological flow. Although this is only a guide it is used as part of the regulation.

Renewable energy policy

In 2016, the Ministry of Energy finished a participative process for the elaboration of a long-term energy policy called "*Energía 2050*", which included the participation of different actors from the Government, industry, general public and universities.[22] This process concludes with the Roadmap 2050 and the 2050 Energy Policy.[23,24] These documents are based on four objectives with one being to generate 60 per cent of the energy from renewable sources by 2035 and 70 per cent by 2050.

In 2018, the Ministry of Energy published the Energy Route 2018-2022, a roadmap for the four years of the new Government with seven lines of action: [25]

- Energy modernization (regulation and institutions);
- Socialization of the projects;
- Energy sector development;
- Low-emission energy, diversifying the energy mix according to the local resources available;
- Efficient transport, promoting the incorporation of electric means of transportation in the public and private sectors
- Energy efficiency, promoting the efficiency in the residential and industrial sectors;
- Energy education and capacitation, considering education programmes in all levels of the society with participation of the private and public sectors.

The more significant compromise made includes time reduction in the environmental approval process and the elaboration of master plan for decommissioning or reconversion of coal power plants.

Barriers to small hydropower development

Chile has abundant energy resources and has made some effort in order to promote the development of renewable energy sources, including SHP. However, there are barriers to their development and implementation. Regarding SHP development, in Chile there are social, institutional and technical barriers.

The social barriers include:

- Ownership of water – hydropower potential is not necessarily perceived as a natural condition of the water resource;
- Use of water – competition for multiple uses in the river basins, such as other productive areas, conservation and tourism;
- Asymmetry of information – lack of information and good communication between the community and the developers, generating mistrust;
- Balance of cost, risk and benefits – lack of information within the community about the cost, potential risk and real benefits associated with the project generates the sensation of being robbed of its resources. The community sees only the external cost and usually overestimates the potential risk and the revenues for the developer;
- The community at large feels left out of the planning of hydropower development;

The institutional barriers include:

- Absence of unified criteria of environmental impact assessment for SHP;
- Long approval process for the environmental and construction permits;
- Water rights can be monopolized;
- Ecological flow included in the water right is not considered in the environmental approval, a new ecological flow has to be defined;
- Water rights legal constitution is under modification.

The technical barriers include:

- Normally, the SHP development is distant from transmission lines, so the project developer has to invest in the lines as well. These transmission costs often make the project unfeasible.

References

1. National Statistics Institute (INE) (2017). 2017 CENSO Results. Available from https://resultados.censo2017.cl/. (accessed May 2017)
2. National Statistics Institute (INE) (2017). National Statistical Compendium. 2017.
3. National Commission of Energy (CNE) (2018). Generation Installed Capacity. Available from https://www.cne.cl/estadisticas/electricidad/. (Accessed 8 October 2018)
4. National Commission of Energy. Energy Statistical Yearbook. 2017. Report.

5. National Commission of Energy. Short-term node price report. July-2018.
6. Ministry of Economy Development and Reconstruction (2018). Standard specifications RPTD N°01: Rated voltage and frequency.
7. Ministry of Economy Development and Reconstruction (2018. Decree with Force of Law 4: General Law of Electrical Services. s.l.: Ley Chile, 2017.
8. Ministry of Mining (2014). Decree 2224: Creates the Ministry of Energy and the National Energy Commission.
9. Ministry of Economy Development and Reconstruction. (2016). Law 18,410: Creates the Superintendence of Electricity and Fuels.
10. Ministry of Energy (2017). Law 20,936. Establishes a new electricity transmission system and creates an independent coordinating body for the national electricity system.
11. Ministry of Economy, Development and Reconstruction (2018). Decree 44: Approves the regulations of the Panel of Experts established in the General Law of Electrical Services.
12. General Ministry of The Presidency (2012). Law 20,417. Creates the Ministry, the Environmental Assessment Service (SEA by its acronym in Spanish) and the Environmental Super intendency.
13. Ministry of Economy (2013). Development and Reconstruction. Law 20.257: Introduces modifications to the general law of electrical services with respect to the generation of electrical energy with non-conventional renewable energy sources.
14. Ministry of Energy (2017). 4eChile: Mini/Micro Hydraulic Power Plant Technology Sheet. Renewable Energy and Energy Efficiency Program. Available from https://www.4echile.cl/4echile/wp-content/uploads/2017/09/fichas-tecnologicas-micro-central-hidraulica.pdf. (Accessed 8.10.2018.)
15. APEMEC (2018). Monthly Brochure - August 2018. 2018. Monthly Brochure.
17. National Commission of Energy (CNE) (2016). Technical standard of connection and operation of PMGD in medium voltage installations.
18. Ministry of Energy (2015). Basis for territorial planning in future hydropower development. Study. Available from: http://dataset.cne.cl/Energia_Abierta/Estudios/Minerg/informe_final_primera_etapa_estudio_cuencas.pdf.
19. National Commission of Energy and National Commission of Irrigation (2007). Hydropower potential estimation associated to existing or project irrigation works.
20. Ministry of Economy Development and Reconstruction (2015). Decree 244. Approves regulation for unconventional generation plants and small plants of generation established in the general law of electrical services.
21. National Congress (2011). Reform of the Water Code. Available from www.senado.cl. Available from http://www.senado.cl/appsenado/templates/tramitacion/index.php?boletin_ini=7543-12. (Accessed 03.10.2018.)
22. Ministry of Energy (2016). Energy 2050 Energy Policy of Chile - documents of the process. Available from http://www.energia2050.cl/es/documentos/. (Accessed 08.10.2018.)
23. Ministry of Energy (2016). Roadmap 2050, Towards a sustainable and inclusive energy for Chile. [Online] September 2015. [Cited: 8 10 2018.] http://www.energia2050.cl/wp-content/uploads/2016/07/Hoja-de-Ruta-2050.pdf.
24. Ministry of Energy (2016). Energy 2050 - Energy Policy of Chile. [Online] 2016. [Cited: 8 10 2018.] http://www.energia2050.cl/wp-content/uploads/2016/07/Politica-Energetica-Nacional.pdf.
25. Ministry of Energy (2016) Energetic Route 2018 - 2022, Leading the modernization with citizen. www.energia.gob.cl. [Online] May 2018. [Cited: 03 10 2018.] http://www.energia.gob.cl/rutaenergetica2018-2022.pdf.
26. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
27. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.

Colombia

2.3.5

Ernesto Torres, Universidad Libre/Católica; International Center on Small Hydro Power (ICSHP)

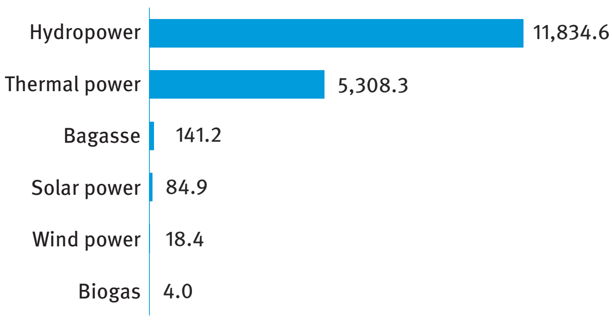
Key facts

Population	48,258,494 [1]
Area	1,240,192 km[2]
Climate	Columbia's equatorial location and the Andes mountain range determine its climactic variations, which are sub-tropical to arid, hot and dry (February to June), rainy, humid and mild (June to November), cool and dry (November to February). Higher altitudes have low average temperatures of below 12 °C, while low altitude areas are much warmer, with averages from 18 °C to 24 °C.[2]
Topography	The topography varies per region, from mountainous highlands to low valleys, plains and coast. To the north of the country is the Sierra Nevada de Santa Marta (5,775 metres), an isolated massif and the highest elevation of the country.[2]
Rain pattern	Average annual precipitation over land is 500-3,240 mm, but varies greatly from year to year and from place to place. The driest region is located in the municipality of Uribia in the Guajira Peninsula, with an average annual rainfall of 267 mm. The Choco region is the wettest, with precipitation exceeding 9,000 mm per year.[2]
Hydrology	The major rivers include the Magdalena, Cauca, Caquetá, Putumayo, Guaviare, Meta and Atrato. In the mountainous areas, torrential rivers on the slopes produce large hydropower potential and add their volume to the navigable rivers in the valleys.[3]

Electricity sector overview

In March 2019, the installed capacity in Colombia was 17,391 MW.[4] The capacity by source was as follows – hydropower approximately 68.1 per cent, thermal power (including gas, coal and fuel) 30.5 per cent, bagasse 0.8 per cent, solar power 0.5 per cent, wind power 0.1 per cent, and biogas 0.02 per cent (Figure 1).[4] Between the end of 2016 and March 2019, installed capacity increased by almost 800 MW.[4,5] The electrification rate in Colombia is 99 per cent, with 100 per cent access in urban areas, while in rural areas this decreases to 96 per cent.[6] Electricity generation in 2017 stood at 67 TWh, of which hydropower accounted for 86 per cent (57 TWh).[7]

Figure 1.
Installed electricity capacity by source in Colombia (MW)



Source: UPME[4]

The Colombian energy industry comprises both public and private players. Private sector involvement was achieved through deregulation in 1990. La Comisión de Regulación de Energía y Gas de Colombia (CREG) is one of the main participants with regulatory oversight.[8,9] The Colombian National Transmission System, a monopoly by nature, is the middleman between the generators and the traders and is regulated by CREG.[9,10]

Eleven companies are involved in transmission, of which the Government-run company Interconexión Eléctrica S.A. E.S.P. (ISA) controls approximately 83 per cent of the market.[9,10] The supply of Colombian electricity is based on the National Interconnected System (SIN) which covers one third of the territory and supplies 96 per cent of the population. Other local systems in the non-interconnected areas provide the remaining 4 per cent of the population mainly residing in the east of the country.[9,11]

As of December 2018, electricity prices per kWh for residential customers ranged between COP 193 (US$ 0.06) and COP 625 (US$ 0.19).[12]

Small hydropower sector overview

Colombia considers small hydropower (SHP) as plants with an installed capacity up to 10 MW. As of March 2019, the installed capacity of SHP in Colombia was 214 MW, while the potential was 25,000 MW.[4,9] Between the *World Small Hydropower Development Report* (*WSHPDR*) *2016* and *WSHPDR 2019*, installed capacity has decreased by 14 per cent, which is due to access to more accurate data. Potential capacity has remained the same (Figure 2).

Figure 2.
Small hydropower capacities 2013/2016/2019 in Colombia (MW)

Source: UPME,[4] *WSHPDR 2016*,[9] *WSHPDR 2013*[13]

Note: The comparison is between data from *WSHPDR 2013, WSHPDR 2016* and *WSHPDR 2019.*

According to the inventory of the Electric Interconnection S.A-ISA, the theoretical potential hydropower capacity is 93,085 MW, spanning 309 inventoried projects larger than 100 MW. From this total hydropower potential, the economically feasible potential is 7,700 MW.[9] According to the National Energy Plan, the SHP potential is 25,000 MW. Despite this enormous potential, only 0.9 per cent of it has been developed. Currently, several regional organizations and regional companies are carrying out portfolios aiming to develop SHP plants.[9]

From the beginning of 2016 to May 2019, the Unidad de Planeación Minero Energética (UPME) received 23 applications for SHP certification, out of which 17 projects with a combined capacity of 54.2 MW (with individual capacity up to 10 MW) were approved.[14]

The financing of SHP plants comes from various sources, namely multilateral development financing, international and bilateral assistance, non-governmental organizations (NGOs), the private sector, the Clean Development Mechanism, the national bank with specific funds for renewable energy projects, the Institute of Planning and Promotion of Solutions (Instituto de Planificacion y Promocion de Soluciones) developing renewable energy projects in non-interconnected zones including SHP plants.[8,9]

Renewable energy policy

Environmental laws concerning general ecological aspects and environmental impacts have been applied in Colombia since the late 1990s. However, all legislation concerning renewable energy was initiated in 2001.[9,15] Law 697/2001 and its Regulatory Decree 3683 of December 19, 2003 provide certain incentives for scholarships, research and development for renewable and alternative energy sources.[9,10]

Resolution 41286 of 30 December 2016 adopted the 2017-2022 Indicative Plan of Action to develop the Programme on Rational and Efficient Use of Energy and other forms of Non-Conventional Energy (PROURE). PROURE gives high priority to several lines of action related to the promotion of non-conventional energy sources, including SHP.[16]

Law 1715 of 2014 regulates the integration of non-conventional renewable energy into the SIN. It aims to incentivize private investment in renewable energy projects through fiscal incentives, such as income tax reduction, value added tax (VAT) exemption, import duty exemption and accelerated depreciation for renewable energy investments.[17]

Legislation on small hydropower

According to Article 3.14 of Law 697/2001, which establishes and promotes the rational and efficient use of energy as well as the use of alternative energy technologies, SHP is defined as the potential energy gained from a hydraulic flow on a certain altitude not exceeding 10 MW of electricity production.[9,18] In addition, Law 697 makes available incentives for research and development in the field of SHP.[9] Moreover, the Government's recent engagement to determine the quantity and localities of non-conventional energy sources (Fuentes No Convencionales de Energia) is in the process of producing a multi-year aggregate SHP potential map.[9,18]

Barriers to small hydropower development

Although SHP plays a vital role in the energy sector, it is not without its problems in Colombia. The key barriers include:

- There are substantial climatic variations in Columbia, which produce lower rainfall impacting energy production.
- The Government is inclined to reduce concrete SHP promotion strategies and incentives in order to slow down SHP development and implementation in Colombia due to the fear of high dependency on a climatic vulnerable energy source.
- Although microfinance institutions (MFIs) are available in Colombia, only three out of the 29 MFIs offer low income loans for micro-, small, medium and large borrowers, thus significantly reducing the support available for SHP investors.
- There is a lack of support systems to identify mechanisms that could be better suited to the characteristics of Colombia.
- There is a deficit in outlined budgeting for scientific research and development.
- Technical norms need to be defined and standardized.
- Rural and urban technical support is lacking.
- Local political instabilities also hinder foreign investment in SHP as many sites are located in areas where guerrilla activities have taken place.[9,19]

References

1. National Administrative Department of Statistics (DANE) (2018). *Censo Nacional de Población y Vivienda 2018.* Available from https://www.dane.gov.co/index.php/estadisticas-por-tema/demografia-y-poblacion/censo-nacional-de-poblacion-y-vivenda-2018/cuantos-somos
2. United Nations Food and Agriculture Organization (2015). *Colombia*. Aquastat database. Available from www.fao.org/nr/water/aquastat/countries_regions
3. United States Library of Congress (1988). *Colombia: A Country Study*. Available from www.countrystudies.us
4. Unidad de Planeación Minero Energética (UPME) (2019). *Capacidad Efectiva de De Generación (SIN).* Available from http://www.upme.gov.co/Reports/Default.aspx?ReportPath=%2fSIEL+UPME%2fGeneraci%c3%b3n%2fCapacidad+Efectiva+de+Generaci%c3%b3n+(SIN)
5. Electric Power Information System (SIEL) (2016). *Informe Mensual de Variables De Generación y del Mercado Eléctrico Colombiano – Diciembre de 2016.* Available from http://www.siel.gov.co/portals/0/generacion/2016/Segui_variables_dic_2016.pdf
6. World Bank (2016). *Access to electricity (% of population).* Available from https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS
7. Electric Power Information System (SIEL) (2017). *Estadísticas y variables de generación.* Available from http://www.siel.gov.co/Inicio/Generaci%C3%B3n/Estad%C3%ADsticasyvariablesdegeneraci%C3%B3n/tabid/115/Default.aspx?PageContentID=1197
8. Mazzeo, F., et. al. (2011). *Overview of Renewable Energies in Colombia, Costa Rica, Italy and Malawi*, 7 November 2011. Escuela de Organizacion Industrial. Available from www.eoi.es/blogs/imsd/overview-ofrenewableenergies- in-colombia-costa-rica-italy-and-malawi
9. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
10. Ruiz, B.J. and Rodríguez-Padilla, V. (2006). *Renewable energy sources in the Colombian energy policy, analysis and perspective*s. Mexico DF: Universidad Nacional Autónoma en México. Available from http://augusta.uao.edu.co/moodle/file.php/3043/Material/EP342006_3684_3690.pdf
11. Quintero, E. T. (n.d.). *Investigacion en Pequenas Centrales en Colombia*. Universidad de Colombia. Available from http://www.unilibre.edu.co/revistaingeniolibre/revista-12/ar9.pdf
12. Enel (2018). *Tarifas de Energía Eléctrica ($/Kwh). Reguladas Por la Comisión de Regulación de Energía y Gas (CREG). Diciembre de 2018.* Available from https://www.enel.com.co/content/dam/enel-co/espa%C3%B1ol/personas/1-17-1/2018/Tarifario-diciembre-2018.pdf
13. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
14. Unidad de Planeación Minero Energética (UPME) (2019). Informe Mensual – Solicitud de Certificación de Proyectos de Fuentes No Convencionales de Energía (FCNE) –Incentivos Ley 1715 de 2014. Informe No. 05. Available from http://www1.upme.gov.co/InformacionCifras/Paginas/Informe-dinamico-FNCE.aspx
15. International Energy Agency (IEA) (2015). *World Energy Outlook 2015*. Available from http://www.worldenergyoutlook.org/
16. Colombia, Ministerio de Minas y Energía (2017). *Indicative Action Plan for Energy Efficiency PAI PROURE 2017-2022.* Available from http://www1.upme.gov.co/Documents/PAI_PROURE_2017_2022.pdf
17. República de Colombia, Diario Oficial (2014). *Ley 1715 de 2013 por medio de la cual se regula la integración de las energías renovables no convencionales al Sistema Energético Nacional*. Available from http://www.comunidadcontable.com/BancoMedios/Imagenes/ley%201715%20de%202014.pdf
18. Business Monitor International (2012). *Colombia Power Report, Q4.* London
19. Colombia, Ministerio de Minas y Energía, Unidad de Planeación Minero Energética (2010). *Formulacion de un Plan de Desarrollo para las Fuentes no Convencionales de Energia en Colombia.* Available from http://www.upme.gov.co/Sigic/DocumentosF/Vol_2_Diagnostico_FNCE.pdf

2.3.6 Ecuador

Alfredo Samaniego Burneo and Luis Manzano, Ministry of Electricity and Renewable Energy; International Center on Small Hydro Power (ICSHP)

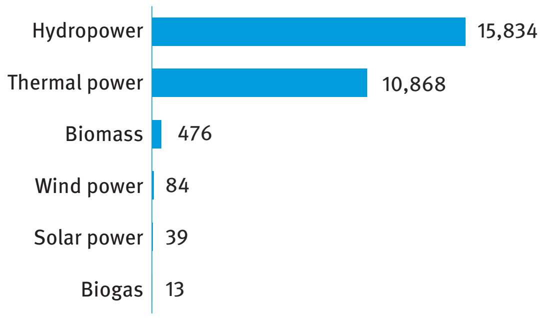
Key facts

Population	16,783,278 [1]
Area	256,370 km^2 [2]
Climate	Annual average temperature in the coastal, oriental region and the Galapagos Islands varies between 25 °C and 26 °C. Temperature changes with the increase in altitude and reaches only between 10 °C and 16 °C on average in regions from 1,500 to 3,000 metres above sea level. Due to its location on the Equator, most of the country is characterized by a humid, tropical climate. Temperature extremes rarely exceed 37 °C or go below 10 °C, therefore weather conditions are mild.[3]
Topography	Ecuador has a diverse topography, which includes a flat eastern jungle, coastal plains and highlands. The country also has an insular region, the Galapagos Islands. Ecuador is considered one of the most biodiverse countries, due to the portions of the Amazon Rainforest within its territory, as well as the Galapagos Islands. The capital city, Quito, is at an elevation of 2,850 metres. The highest altitude in Ecuador is 6,267 metres, at Mount Chimborazo.[4]
Rain pattern	Annual rainfall averages between 200 mm and approximately 5,000 mm, depending on the region. Quito records roughly 1,004 mm of rain each year. Drier regions such as San Jacinto de Buena Fe, Cumanda and Teresita receive only 284 mm of precipitation per year.[5]
Hydrology	There are at least 2,000 rivers and streams in Ecuador. However, the abundance of water resources in the country has caused multiple conflicts and the Government has approved projects that use more water than is available.[6] The Amazon River, the largest in the world, crosses Ecuador. Maranon and Putumayo are other major rivers, which Ecuador shares with other countries in South America such as Peru.[7]

Electricity sector overview

At the end of 2016, the total generation of electricity in Ecuador was 27,314 GWh. According to the Government of Ecuador, the production of electricity increased by 58 per cent in the past ten years.[8] Hydropower accounted for approximately 58 per cent of the total generation, thermal power for 40 per cent and other renewable resources such as biomass, wind power, solar and biogas, for approximately 2 per cent. Most of the hydropower plants in Ecuador are medium or large.[8,9] Figure 1 offers more details on the generation of electricity by source in Ecuador.

Figure 1.
Annual electricity generation by source in Ecuador (GWh)

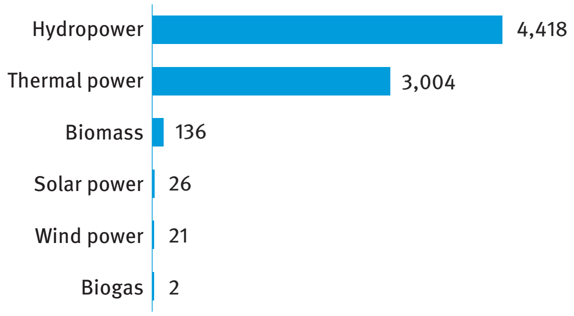


Source: Agencia de Regulacion y Control de Electricidad,[8] Huertas & Estrada[9]

The total installed electricity capacity was 7,606.9 MW at the end of 2016.[8] Figure 2 offers comprehensive information on installed capacity by source. To facilitate reading, the statistics were rounded to an annual total of 7,607 MW. The substantial increase in both installed capacity and annual electricity generation is due to the completion of new plants that went into operation in 2016. Hydropower plants Coca Codo Sinclair with an installed capacity of 1,476 MW and Sopladora 487 MW are the most important additions to the electricity mix of the country.[9]

Other power plants that commenced operation in 2016 were the 42 MW Baba and the 27 MW Topo hydropower plants. In addition, three small hydropower plants also commenced operation in 2016 (Victoria: 10 MW, Hydrotambo: 8 MW, Central Alazan: 6.23 MW) and one biogas facility, El Inga, with 2 MW installed capacity.[9] Despite the substantial increase in thermal plants and thus in the use of fossil fuels for electricity generation, energy supply depends widely on hydrological behaviour of the rivers connected to the reservoir power stations. The National Transmission System encompasses lines and sub-stations which operate on standardized voltage of 500 kV, 230 kV and 138 kV.[9]

Figure 2.
Installed electricity capacity by source in Ecuador (MW)



Source: Agencia de Regulacion y Control de Electricidad,[8] Huertas & Estrada[9]

According to the World Bank, 99.9 per cent of the population in Ecuador had access to electricity in 2016. It is believed that this figure has now reached 100 per cent. However, the electricity system is still unreliable, with frequent interruptions, power outages and losses. Electricity access for the population in rural areas reached 99.8 per cent in 2016.[10]

The Agency for the Regulation and Control of Electricity (ARCONEL) has among its responsibilities the regulation and scheduling of tariffs, ensuring of fair and effective functioning of the electricity sector in Ecuador. Article 3 of the Law of Ecuador defines the agency's responsibilities as creating a tariff structure to apply to consumers or end users and ensuring the quality and efficiency of public electricity and general lighting services.[11]

Table 1.
Monthly electricity tariffs for industrial consumers in Ecuador

Type of consumer	*Voltage*	*Price range (US$/month)*
Crafts industry	0 kWh – 300 kWh (LV)	0.15 – 0.76
	> 300 kWh	1.08 – 6.07
Other industries	0 kWh – 300 kWh (LV)	1.61 – 47.2
	(MV)	1.84 – 71.65
	(HV)	276.15 – 4,000

Source: Agencia de Regulacion y Control de Electricidad[11]

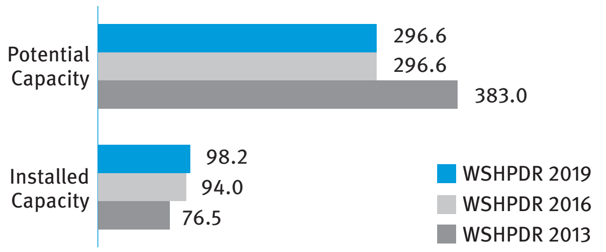
Note: LV= low voltage, MV = medium voltage, HV= high voltage

The tariff for electricity varies a lot based on electricity provider, nature of the client and consumption range. The electricity providers in Ecuador are Corporacion Nacional de Electricidad (CNEL EP), Empresa Electrica Galapagos, Empresa Electrica Sur, Empresa Electrica Riobamba, Empresa Electrica Quito, Empresa Electrica Norte, Empresa Electrica Cotopaxi, Empresa Electrica Centro Sur, Empresa Electrica Azogues and Empresa Electrica Ambato. Prices vary between US$ 0.15 and US$ 0.76 per month for the crafts industry, for consumption between 0 kWh and 300 kWh. For consumption of electricity beyond 300 kWh, tariffs vary from US$ 1.08 to US$ 6.07 per month. Other industries prices start at US$ 1.61 per month and increase based on the demand, reaching up to US$ 47.2 per month. Prices for medium voltage electricity, for the industry start at US$ 1.84 per month and costs may be as high as US$ 71.65 per month, depending on the demand and on the choice of provider. Costs of high voltage electricity are set much higher, varying from US$ 276.15 per month to approximately US$ 4,000.[11] A more detailed distribution of costs by provider can be accessed from the official online platform of the Electricity Regulation and Control Agency in Ecuador. Table 1 below offers more information on the monthly price ranges for industry in the electricity sector.

Small hydropower sector overview

The total installed capacity of small hydropower plants up to 10 MW was 98.2 MW at the end of 2016. The Victoria small hydropower plant of 10 MW, the Hydrotambo plant of 8 MW and the Central Alazan plant of 6.23 MW only commenced operation in 2016. Certain SHP plants in Imbura province underwent refurbishment, which increased their installed capacity, no longer complying with the definition for SHP that the *World Small Hydropower Development Report (WSHPDR)* uses.[8] These plants were not included in Figure 3. No updated information was made available with regards to the potential capacity of the country, therefore potential capacity remains at 296.6 MW, based on the feasibility studies conducted.

Figure 3.
Small hydropower capacities 2013/2016/2019 in Ecuador (MW)



Source: Agencia de Regulacion y Control de Electricidad,[8,12] *WSHPDR 2013*,[13] *WSHPDR 2016*[14]

Note: The comparison is between data from *WSHPDR 2013, WSHPDR 2016* and *WSHPDR 2019.*

The total installed capacity of 98.2 MW comes from 37 small hydropower plants of up to 10 MW.[8] The Government of Ecuador has approved the construction of additional small hydropower projects in the country. Different companies are in charge of the development of these projects. Hidrosierra S.A. oversees the installation of a small hydropower plant of 10 MW which is expected to generate approximately 83 GWh per year. Hidroequinoccio EP was also awarded a 10 MW hydropower project which will produce roughly 77 GWh per year. CELEC EP will be overseeing the construction of two plants, one of 7.19 MW and another of 4 MW, generating 44.9 GWh and 23 GWh respectively. Lastly, San Jose de Minas S.A. is in charge of the construction of a 5.95 MW power plant which is expected to generate 37 GWh per year. The completion of the aforementioned projects is expected to occur between 2018 and 2023.[12]

Ecuador is one of the very few Latin American countries that implemented a feed-in tariff (FIT) scheme for renewable energy. The FIT scheme was approved in 2013 by the Government of Ecuador and replaced the previous one that had ended in 2012. The FIT contracts are awarded for a period of 15 years. For small hydropower of up to 10 MW, the FIT rate is 0.0781 US$/kWh. It was also specified that once the country achieves 6 per cent of its total installed capacity from renewable energy sources, excluding large hydropower, the programme will close. In case of not reaching the target, the programme would have expired on the December 31, 2016.[15]

Renewable energy policy

According to the statistics provided in the current report, the objective stated in the National Plan for Good Living (PNBV) 2013 – 2022 to reach 60 per cent of the country's capacity from renewable energy resources by 2017 has been reached. This target put special emphasis on hydropower of all sizes and bioenergy projects. The very same national plan approved by the Government of Ecuador proposed 25 hydropower projects to be constructed by 2022. The plants will have an overall installed capacity of 4.2 GW. In addition, 217 MW of solar, wind and other non-conventional resources will also be installed by 2022.[16]

The Electric Law of 1996 offered import duty and income tax exemptions to renewable energy developers for solar, wind, geothermal and biomass facilities. The 2015 Electric Law does not stipulate these incentives anymore. Since 2011 it was mandatory for FIT-sponsored renewable energy projects to contribute an amount per each kWh generated to social and community projects. The amount specified in Table 1 below is reflective of the contribution of these projects to social and community development as of 2014.[16]

Table 2.
Contribution required for renewable energy technologies as of 2014

Technology	*Contribution required (US$/kWh)*
Biogas	0.0165
Hydropower (<30 MW)	0.0189
Biomass	0.0238
Wind power	0.0239
Geothermal	0.0336
CSP*	0.0874
Solar PV	0.1180
Ocean	0.1277

Source: Norton Rose Fulbright[16]

Note: *CSP = Concentrated Solar Power Systems (systems function based on mirrors or lenses that facilitate electricity production by achieving a substantial concentration of sunlight).

Most renewable energy projects in Ecuador are developed by state-owned entities. The country aims to ensure environmental protection and extend energy coverage by financing key projects.

Barriers to small hydropower development

While the Ecuadorian Ministry of Electricity and Renewable Energy is making considerable efforts to ensure higher reliability and resilience of the energy sector, there are still a wide variety of challenges with regards to SHP adoption, as outlined below.

- Lack of detailed data with regards to economic and technical potential of small hydropower in Ecuador affects investment decisions and policies in the sector;
- Lack of technical capabilities and knowledge to ensure effective integration of small hydropower technology into the power system;
- Dependency on large hydropower, making larger projects a priority for the Government and limiting the focus on small hydropower investment;
- Lack of reliable information for the private sector and for international investors, as most data available is based on theoretical predictions.[17]

There is an imperative need to define a more comprehensive strategy on small hydropower project implementation and on encouraging future public-private partnerships. With the more active involvement of the private sector, Ecuadorian Government has the potential to ensure effective dissemination of small hydropower across the country.

References

1. Instituto Nacional de Estadísticas y Censos (INEC) (2018). Datos de Población Ecuador. Ecuador en cifras. Available from http://www.ecuadorencifras.gob.ec/estadisticas/
2. World Bank (2017). Surface área (sq. km). World Development Indicators. Databank. Available from https://data.worldbank.org/indicator/AG.SRF.TOTL.K2?locations=EC 3. Instituto Nacional de Meteorología e Hidrología (INAMHI) (2017). Publicaciones Meteorologicas. Available from http://www.serviciometeorologico.gob.ec/biblioteca/
4. Briney, A. (2017). Geography of Ecuador. Updated on 17 March 2017. Available from https://www.thoughtco.com/geography-of-ecuador-1434572
5. Climate Data Organization (n.d.) Climate: Ecuador. Available from https://en.climate-data.org/country/63/
6. Terry, M. (2007). Ecuador's Water Crisis: Damming the Water Capital of the World. International Rivers Organization. Available from https://www.internationalrivers.org/resources/ecuador-s-water-crisis-damming-the-water-capital-of-the-world-1895
7. Sawe, B. E. (2017). Major Rivers of Ecuador. World Atlas. Last updated on April 2017. Available from https://www.worldatlas.com/articles/major-rivers-of-ecuador.html
8. Agencia de Regulacion y Control de Electricidad (2017). Atlas del Sector Electrico Ecuadoriano 2016. The Government of Ecuador. Available from http://www.regulacionelectrica.gob.

ec/wp-content/uploads/downloads/2017/08/Atlas2016BajaV6_baja_113_1era_parte.pdf
9. Huertas, A.C. & Estrada, L.M. (2017). Como mejorar la gestión energética en Ecuador (Abril de 2016). Available from https://www.scribd.com/document/377675337/Como-Mejorar-La-Gestion-Energetica-en-Ecuador
10. World Bank (2017). Access to electricity (% of population). Sustainable Energy for All Database. Available from https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS
11. Agencia de Regulacion y Control de Electricidad (2018). Pliego Tarifario para las Empresas Electricas de Distribucion. Servicio Publico de Energia Electrica. January – December 2018 Prices. Available from http://www.regulacionelectrica.gob.ec/wp-content/uploads/downloads/2018/01/2018-01-11-Pliego-y-Cargos-Tarifarios-del-SPEE-20182.pdf
12. Agencia de Regulacion y Control de Electricidad (2017). Atlas del Sector Electrico Ecuadoriano 2016 – Second Part. The Government of Ecuador. Available from http://www.regulacionelectrica.gob.ec/wp-content/uploads/downloads/2017/08/Atlas2016BajaV6_baja_113_2da_parte.pdf
13. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
14. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
15. International Energy Agency (IEA) (2018). Ecuador feed-in tariff for renewable energy. Global renewable energy. IEA/IRENA Joint Policies and Measures database. Available from http://www.iea.org/policiesandmeasures/pams/ecuador/name-42887-en.php?s=dHlwZT1yZSZzdGF0dXM9T2s,
16. Norton Rose Fulbright (2016). Renewable Energy in Latin America: Ecuador. October 2016. Available from http://www.nortonrosefulbright.com/knowledge/publications/134775/renewable-energy-in-latin-america-ecuador
17. Renewable Energy Generation in South America (n.d.). Comparative Analysis of Institutional and Technical Conditions Relevant for the Integration of Renewable Energy in South America. An European Union funded project. Available from http://regsa-project.eu/downloads/Public%20documents/regsa_summary.pdf

2.3.7 French Guiana

International Center on Small Hydro Power (ICSHP)

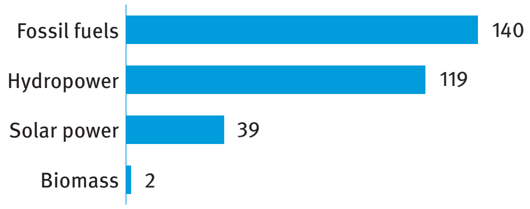
Key facts

Population	242,893 [1]
Area	83,534 km^2 [1]
Climate	The climate of French Guiana is tropical. It has a dry season between August and December and a rainy one from December to July. There is not a lot of variation in the weather, days being hot all year round and nights cooler. Average temperatures reach 27 °C.[2]
Topography	Situated on the north-east coast of South America, French Guiana borders Brazil to the south and east and Suriname to the west. This overseas region of France consists of a coastal strip and dense, almost inaccessible forest. While its area is large, the majority of its population lives in the coastal strip. Rainforest still covers most of the country's territory. Due to its important natural resources, Guyana Amazonian Park was created in 2007, the region enclosed becoming a protected area. The highest peak is Bellevue de I'lnini (851 metres). Other mountains are Mont Macalou (782 metres), Pic Coudreau (711 metres) and Mont St. Marcel (635 metres). Off the coast, there are a number of small islands. Ile de Connetable and Devil's Island are two of the most known, located along the coast towards Brazil.[2,9]
Rain pattern	French Guiana experiences an average annual rainfall between 2,500 and 3,000 mm, sometimes reaching 3,744 mm per year. September is the driest month, with an average of 32 mm of rainfall. May is the wettest month, reaching an average of 590 mm of rainfall.[10]
Hydrology	Water resources are rich in French Guiana, with most of its rivers flowing north from the southern mountains. The major river is the Maroni, located between French Guiana and Suriname. Its middle course is called Lawa and it is a popular location for gold mining. Other important rivers are the Oyapok, bordering Brazil and the Approuaque, Camopi, Mana and Tompok.[3] On the estuary of the Mahury River is the main seaport, Dégrad des Cannes.

Electricity sector overview

The total installed capacity in 2015 was 300 MW. Roughly 53.3 per cent (160 MW) was from renewable sources, namely, hydropower, biomass, and solar. Fossil fuels accounted for the remaining 46.7 per cent (140 MW). The total installed capacity of hydropower remained unchanged, at 119 MW. The installed capacity of solar power was 39 MW, biomass 2 MW and fossil fuels 140 MW.[12] Figure 1 is a graph-representation of the installed capacity in French Guiana by source.[4]

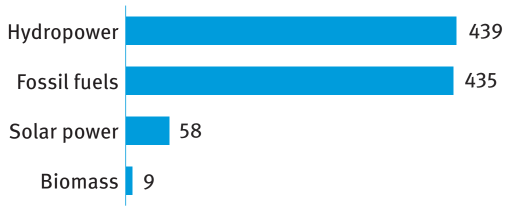
Figure 1.
Installed electricity capacity by source in French Guiana (MW)



Source: UN,[4] World Energy Council[12]

In 2016, 941 GWh of electricity was generated in French Guiana and fed into the grid. Out of the 941 GWh, 439 GWh were generated from hydropower, 435 GWh from fossil fuels, 9 GWh from biomass and 58 GWh from solar power (Figure 2).[11]

Figure 2.
Annual electricity generation by source in French Guiana (GWh)



Source: UN[11]

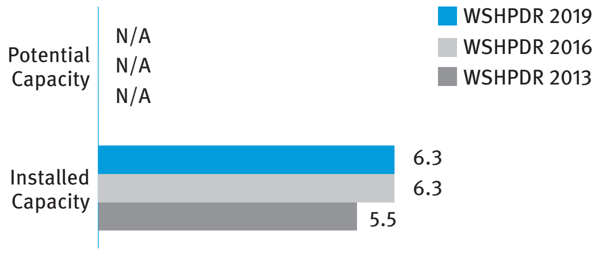
According to late 2016 statistics, roughly 30 to 35 per cent of the population lacks access to electricity and clean water resources. This issue has led to regional protests and demands for investment.[13] The electric grid only covers the territory closer to the coast. Some isolated communities receive power from small isolated systems, while others do not have electricity supply. Large electric generators power inland towns. The regional authority overlooking electricity generation is Électricité de France (EDF), which mainly exploits gas and hydropower resources. There are frequent power cuts in French Guiana, even though the inland areas have access to electricity.[5]

EDF owns the monopoly in the electricity generation sector of French Guiana. Due to its influence in the region, EDF seeks to improve its services by investing in a system capable of managing 24 hours a day a balance between demand and supply of electricity. According to their 2016 report, electricity consumption demonstrated a 3.8 per cent growth in comparison to 2015 data, reaching 823 GWh. This increase might also be explained by the recent development of the economic and demographic activity of French Guiana. The national solidarity fund provides electricity subsidies for the population of French Guiana. Electricity is sold at a much lower price than its production costs, with electricity being sold at half the price it costs to produce. [5,14]

Small hydropower sector overview

The definition of small hydropower (SHP) in French Guiana is plants of up to 10 MW. The installed capacity of SHP remains at 6.3 MW. Between the *World Small Hydropower Development Report* (*WSHPDR*) *2016* and *WSHPDR 2019*, the installed capacity did not change. Lack of funding in the field of SHP, as well as the growing popularity of electricity generated through solar power, makes investment in this sector less probable.

Figure 3.
Small hydropower capacities 2013/2016/2019 in French Guiana (MW)



Source: *WSHPDR 2013*,[5] Voltalia,[7] *WSHPDR 2016*[15]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016 and WSHPDR 2019.*

The two SHP plants in operation are La Mana, with an installed capacity of 4.5 MW, and Saut-Maripa, with a capacity of 0.88 MW.[6] The la Mana hydropower plant on the Mana River had a 20 per cent increase in its installed capacity, from 4.5 MW to 5.4 MW in 2014.[7] Approximately 5 per cent of all installed hydropower capacity in the country is SHP. SHP potential capacity figures for French Guiana are unavailable, but several sites were identified on the Mana, Compté and Approuague rivers. These sites might produce 7 MW to 15 MW in the near future.[8,15]

SHP in French Guiana is highly dependent on rainfall. Monthly data for 2016 collected by EDF clearly shows that the highest production from hydropower happens in May, which is also the wettest month of the year. Throughout May, it was found that hydropower sources can continuously provide electricity and cater for the existent demand. In December, hydroelectric power generation is much lower than in the previous months. Therefore, at that time thermal power plants are more frequently used.[14]

The European Community implemented special conditions in areas described as 'islands', with non-interconnected power systems. As a consequence, the emergence of an energy-sector competitive market is not allowed. The oversea region of France received an exemption from the European Community in favour of developing and implementing 'small isolated systems'. Therefore, the utilities of French Guiana are not required to separate network management from business.[8]

Renewable energy policy

According to Article 73 of the Constitution, while French law is implemented in French Guiana, it can also be altered to meet specific traits of this overseas region of France. As a result, the Climate Plan has been applied to French Guiana, with the territory aiming to reduce greenhouse gas (GHG) emissions by a quarter before 2050. In October 2008, the National Assembly voted in favour of the Grenelle de l'Environnement (Environmental Forum) Law. This law mainly addresses the overseas departments of France, including French Guiana. It asserts that 50 per cent of the energy consumption in French Guiana, Guadeloupe, Martinique and La Réunion will be from renewable sources by 2020, thus the territories will gradually achieve energy independence.[5,15]

French Guiana has rich natural resources, and more specifically forests. The resulting large supply of biomass is predicted to lead to the faster and effective development of that resource. Kourou biomass factory is already in operation and has an installed capacity of 2 MW, while other similar projects are already underway. It is estimated that by 2020 biomass stations will be contributing over 20 MW.[8,15] While there are no special SHP policies implemented on the territory, both the large reserves of biomass and photovoltaic solar energy are increasing in popularity, with more facilities being under construction. Multiple farms and villages in French Guiana depend on electricity generated through solar power. It is expected that within the next few years over a dozen villages located on the borders of the Maroni and Oyapock rivers should have electricity supply.[8]

In 2017, Ségolene Royal established a new energy programme for French Guiana, signing a decree that the territory aims to use solar, hydropower and biomass sources to reach 85 per cent of electricity generated through renewables by 2023. The plan was developed in collaboration with Mainland France, with the territorial community of French Guiana agreeing to implement measures that will enable its population to save

150 GWh electricity, annually. France will most probably also provide additional funding for renewable energy programmes in French Guiana. So far, it has recently awarded funding to projects entitled "534 MW utility-scale solar" and "20 MW of self-consumption PV".[16] More mid- and large-scale solar projects might be developed in the next few years.

The local Government also hopes to develop wind power in French Guiana. Roughly 40 MW is expected to be installed over the next few years. There is uncertainty with regards to whether a large project might be successful due to the intermittent and fluctuating nature of this specific energy source. However, a wind farm of up to 12 MW is a possibility, taking into account the average strength of the wind.[8,15]

Barriers to small hydropower development

Effectively exploiting the potential of SHP in the region is highly dependent on numerous factors, such as weather conditions and existent financial and political incentives. There are multiple barriers to SHP policies implementation in French Guiana, as outlined below.

- The flat topography of the territory as well as the natural climatic variations make it more difficult to develop SHP.
- Geographical isolation and the high demographic growth are factors that negatively affect the likelihood of foreign and private investment in the renewable energy projects.
- Shared borders with Brazil and Suriname might be of the causes of current high crime rates, as there is a lack of control in the region. This also deters foreign investment in the region.[6]
- Lack of financial incentives and governmental schemes as well as low population density makes it less attractive to develop SHP.[5,15] It takes long-term investment and substantial project funding to build the infrastructure necessary for such projects and to ensure there are trained specialists able to manage and operate these facilities.
- The local Government as well as overseas investment focused, more recently, on solar power and biomass development, while there has limited interest in SHP.[6,15]

References

1. UNdata (2015). *French Guiana.* Available from http://data.un.org/CountryProfile.aspx?crName=French%20Guiana.
2. World Travel Guide (n.d.). *French Guiana Weather, climate and geography.* Available from http://www.worldtravelguide.net/french-guiana/weather-climate-geography.
3. World Atlas (n.d.). *French Guiana Geography.* Available from http://www.worldatlas.com/webimage/countrys/samerica/frenchguiana/gfland.htm.
4. UNdata (2015). Electricity, installed capacity of electric power plants, French Guiana. Available from http://data.un.org/Data.aspx?q=installed+capacity&d=EDATA&f=cmID%3aEC
5. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013.* United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
6. The International Journal on Hydropower and Dams (2015). *2015 World Atlas & Industry Guide.* Available from www.hydropower-dams.com
7. Voltalia (2014). *Increased capacity at the Mana hydropwer plant.* Available from http://www.voltalia.com/upload/voltalia/Communique_Presse/2014/Anglais/20141006-Increased-capacity-Mana-hydropower-plant-EN.pdf.
8. Geographic Guianas (n.d.). *Renewable energy: What does the future hold for French Guiana?* Available from http://www.guianas-geographic.com/n%C2%B04/renewable-energy-what-does-the-future-hold-for-french-guiana/.
9. New World Encyclopedia. French Guiana. Available from http://www.newworldencyclopedia.org. (checked on February 2018)10. Climate Temps. French Guiana Precipitation. Available from http://www.french-guiana.climatemps.com (checked on February 2018)11. United Nations Statistics (2016). Total Electricity Production. Energy Statistics Database. Available from http://unstats.un.org/unsd/energy/edbase.htm
12. The World Energy Council (2016). Solar Power in French Guiana. Available from. https://www.worldenergy.org/data/resources/country/french-guiana/
13. Dorsey, D. (2017). Neglected for Decades, French Guyana Demands Investments and Not Charity from France. Atlanta Black Star14. Électricité de France (EDF) (2016). Bilan Électrique EDF SEI 2016. Available from https://www.edf.fr/sites/default/files/contrib/groupe-edf/premier-electricien-mondial/la-strategie-d-edf/edf-territoires-insulaires/bilan-electrique-sei-2016.pdf
15. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016.* United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
16. Kenning, Tom (2017). Solar Focus in French Guiana energy programme, renewables given grid priority.PV-tech. Available from https://www.pv-tech.org

2.3.8

Guyana

Sven Homscheid-Carstens, Hydropower Consultant; Morsha Johnson-Francis, Ministry of Public Infrastructure of Guyana; Mahender Sharma, Guyana Energy Agency; Horace Williams, Hinterland Electrification Company Inc.; and International Centre for Small Hydro Power (ICSHP)

Key facts

Population	777,859[1]
Area	214,970 km[2]
Climate	The climate is tropical, characterized by high temperatures and humidity. Temperatures average 25 °C with little variation throughout the year.[2]
Topography	The terrain is mainly tropical rainforest with flat areas at the coastline and some mountainous areas in the so-called Hinterland. The Pakaraima Mountains in the west rise to 2,772 metres at Mount Roraima, which is the highest point of Guyana.[2,3]
Rain pattern	Precipitation is generally high ranging from 1,500 mm to over 4,000 mm, with a pronounced rainy season from May to August and a shorter one from December to January.[2]
Hydrology	Guyana is called the 'Land of Many Waters' owed to the abundance of streams, rivers and creeks. The largest waterways are the Corentyne, Berbice, Essequibo and Demarara Rivers. Particularly in the relatively unpopulated southern part of the country, there are many falls along the rivers while the rivers' gradients decrease towards the more densely populated areas at the coastline.[2]

Electricity sector overview

The electricity system of Guyana consists of the integrated network at the coast, which supplies electricity to approximately 90 per cent of the population, and various clustered island systems in Region 3 (Essequibo Islands-West Demerara) and in the Hinterland, which supply individual smaller communities and mines. While the electrification rate at the coast is high, most of the Hinterland communities do not have a regular electricity supply. In 2016, the nationwide electrification rate stood at 84 per cent, including 90 per cent in urban areas and 82 per cent in rural areas.[4]

The country's primary electricity utility is Guyana Power and Light Inc. (GPL), a wholly Government-owned, vertically integrated utility company whose licence will expire in 2024. In many smaller Hinterland communities such as Lethem, Mahdia and others, Government-owned electricity companies supply electricity to public institutions and households. In some cases, it is provided on a 24-hour basis and in others, for several hours per day only. In the Hinterland electricity systems, various private electricity providers are established, foremost in conjunction with mining operation that supplies the nearby communities with electricity.[5]

Electricity is mainly produced with diesel and heavy fuel oil (HFO) generators, with the exception of a small share of co-generation from bagasse and both on-grid and off-grid solar power systems. In 2017, GPL supplied its customers in the coastal area with 809.4 GWh of electricity, of which approximately 9 per cent was from an HFO-biomass co-generation plant operated through an IPP (Figure 1).[6]

Figure 1.
Annual electricity generation by source in Guyana (GWh)

Source: GPL[6]

GPL's installed capacity in 2017 was approximately 151.8 MW (excluding the 10 MW HFO and 30 MW bagasse co-generation capacity privately owned by Skeldon Energy Inc.), the available capacity was approximately 131.2 MW. Together with the generators in the Hinterland electricity supply systems, the installed capacity is approximately 162.7 MW. The peak demand in the coastal area system is at 127 MW.[6]

Transmission voltage level is 69 kV and feeder and distribution voltage level is generally 13.8 kV or 11 kV, domestic supply voltage is 110 V at a frequency of 60 Hz.[6,7] The infrastructure in the GPL system is aged, causing frequent service interruptions resulting in many businesses operating off-grid or using their own diesel generators as backup (the total capacity of such units is unknown). In the Hinterland, electricity supply is also rather erratic and available mostly only for several hours per day. The combined technical and non-technical losses of the coastal system are approximately 30 per cent.[6]

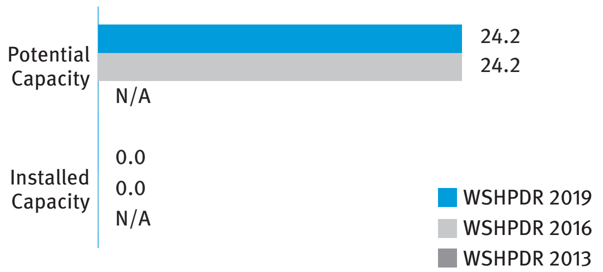
The Public Utilities Commission (PUC) regulates the electricity sector. The National Energy Policy and the Electricity Sector Reform Act (with 2010 Amendments) provide the platform for the participation of independent power producers (IPPs). The Guyana Energy Agency (GEA) is mandated to advise the Minister with the responsibility for electricity and energy in matters related to energy, execute studies, formulate energy policies and regulate the import of petroleum products, but has no general role as an electricity or energy sector regulator. Besides the GEA, there is Hinterland Electrification Company Inc. (HECI), which is attached to the Ministry of Public Infrastructure and is responsible for the electrification of the rural communities. The office of the minister with responsibility for energy, currently the Minister of Public Infrastructure, issues licences for IPPs or electric utilities.[5]

GPL's residential, commercial and industrial rates are US$0.21, US0.27 and US$ 0.24 per kWh on average, respectively. Rates in the Hinterland systems are higher with generation cost ranging as high as US$0.50 per kWh. Current electricity tariffs are by far not cost reflective and the Government subsidizes Hinterland operations and GPL's operation when fuel prices are high.[8]

Small hydropower sector overview

The definition of small hydropower used by Guyana is up to 5 MW. There is no installed small hydropower capacity in Guyana. However, potential capacity is estimated to be 24.17 MW for the 5 MW threshold and 92.1 MW for the 10 MW threshold.[8] Compared to the *World Small Hydropower Development Report (WSHPDR) 2016*, both installed and potential capacities remained unchanged (Figure 2).

Figure 2.
Small hydropower capacities 2013/2016/2019 in Guyana (MW)



Source: *WSHPDR 2016*,[5] GEA,[8] *WSHPDR 2013*[9]

Note: The comparison is made between data from the *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

The National Energy Policy of 1994 speaks of small hydropower in the capacity range between 500 and 5,000 kW.[10] Some sources estimate the country's overall hydropower potential at 7,000 MW. Although Guyana has a track record of hydropower use, at the moment not a single hydropower plant is operational. The Guyana Energy Agency has published on its web page a list of 67 potential hydropower sites that were identified through numerous studies. Based on those studies estimated SHP potential is 24.165 MW.[11]

Currently, hydropower initiatives are considered and supported by the Government of Guyana. The Guyana Power Sector Policy and Implementation Strategy was passed by the Cabinet in 2010 outlining the way forward for hydropower development.[8]

The 165 MW Amalia Falls hydropower project was supposed to be implemented by foreign investors with financing by the IDB and was supposed to supply the coastal area with electricity. The IDB withdrew its financing offer following a market due diligence, an operational assessment of GPL and a financial due diligence of GPL performed by a British consulting firm. The main reason was the rising prices for commodities and financing, which increased the project cost significantly.[5,12]

After the Government stalled the development of the Amaila Falls project, its interest has reopened towards small hydropower projects. Therefore, projects such as Moco-Moco, Tumatumari, Kato and others are now reconsidered and support is sought from international assistance agencies for their implementation. Various SHP projects were studied through the feasibility stage and some even further.

The 150 kW Kato project is expected to serve for rural electrification in Region 8, and financing from the Global Environment Facility (GEF) through the Inter-American Development Bank (IDB) and the Government of Guyana has been secured. Tendering of the works concluded in the fourth quarter of 2018 and construction is scheduled to commence in early 2019, subject to the responsiveness of the bids and the evaluation process.[8]

With funding from the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) and public finance, a 20 kW hydropower plant is currently being constructed at the Hosororo Falls in Region 1 with expectations for completion in early 2019.[8]

GEA's engineers have prepared feasibility studies for a site with 1 MW potential at Ikuribisi, Region 7 and a 1.5 MW site at Kumu, Region 9. These projects are being reviewed to determine possible sources of financing.[8]

GEA is also currently reviewing the feasibility study of the 3 MW Eclipse Falls project, which was carried out with the support from the Democratic People's Republic of Korea in 1985. In seeking to develop the Ilubia hydropower site located in the village of Paruima, Region 7, the GEA engineers in collaboration with the hydro-meteorological office installed a water level gauge and staff gauge on the Ilubia River, conducted flow measurements and assessed the layout of the village in relation to the site and its current mini-grid using a drone. The capacity is estimated to be 100 kW.[8]

Furthermore, the existing but non-operational 500 kW hydropower plant Moco-Moco, close to the town of Lethem, had been financed and built in 1996 with the support from the Chinese Government. However, in 2003 a landslide destroyed the penstock and a fire in the powerhouse rendered the electrical equipment useless.[5] Studies had been conducted to rehabilitate the plant. As of July 2019, the process of finalizing funding for the rehabilitation project was underway, with the plan including an upgrade of the plant to 700 kW.[8]

The 1.5 MW Tumatumari hydropower project on the Potaro River was put in operation in 1959 for power supply to a mining company. Afterwards it was operated to supply the nearby settlements until the plant was decommissioned in the early 1990s. Tumatumari Hydropower Inc. is currently entertaining efforts to rehabilitate the site, presently to no tangible outcome.[5,8]

Renewable energy policy

Due to the country's wealth in fauna and flora, each new project must be scrutinized for its ecological compatibility. Environmentally-friendly projects, however, are welcomed and have good chances of being approved. The Environmental Protection Agency provides basic requirements for acquiring environmental authorization for hydropower project developments. However, this is the country's first experiences of setting rules for environmental evaluation and further elaboration thereof will be required. Currently, the Government prepares to attract developers of small hydropower projects by means of public tendering processes for selected projects. The details of the process are yet to be defined but a Public-Private Partnership Policy Framework was developed in 2018 for infrastructure projects including hydropower plants and energy farms.[8]

The National Energy Policy of Guyana of 1994 contains an outlook from 1994 to 2004. In 1994, the policy already prescribed energy conservation and a preference for indigenous energy sources over imported fuels. The 1994 policy was outdated and required modernization considering the latest technological and other developments. This policy was updated in the form of a Green Paper in 2017 and public consultations are underway in tandem with the development of the Green State Development Strategy. There are no feed-in tariffs for electricity generated from renewable energy (RE) sources. RE developments are granted tax concessions for 10 years.[5,8] The Electricity Sector Reform Act of 1998 mentions the use of renewable and alternative energy but does not explicitly promote the use thereof by creating preferences or other incentives.[5,13]

In the past, there was no structured approach to developing the country's hydropower resources. Instead of the Government taking a proactive role in developing the resources by tendering concessions or generation capacity portfolios, it responded to proposals brought forward on the initiative of individual developers. Currently, the approach of public tendering of project sites or concessions is being tried with clearly outlined rules for participants in the bidding process. In 2016, the Cabinet issued instructions to invite proposals from interested groups for RE supply for the Bartica community, Lethem (Moco-Moco) and other identified communities. However, the degree to which the Government will support the financing arrangements is not clear yet.[5]

Due to the inexperience and lack of precedence in the development and operationalization of hydropower plants in Guyana, potential developers see themselves confronted with obscure processes for obtaining the various licences and meeting the rules for the application and project development process. This results in uncertainty for developers regarding the application duration, application cost and likely outcomes. This applies to planning licences, operating licences, environmental permits and any other applicable permits. The Government of Guyana has introduced a web-based platform for investors, but it is still in its development stage.[14] Developers typically put forward high expectations regarding revenue and payback time, which the projects are rarely able to satisfy. On the other hand, the Government did not grant sovereign guarantees for such projects in the past, which, if done, would make it easier and cheaper for developers to mobilize financing. Here, both parties need to seriously consider the advantages and disadvantages of initiatives to de-risk such hydropower projects.

Barriers to small hydropower development

The main barriers to small hydropower development in Guyana include:

- The great distances between hydropower sites and load centres and the difficult access into the Hinterland;
- High development costs and low financial attractiveness of projects for private investor intervention without subsidies;
- In most cases, the construction of expensive access roads has to be included into the project budget jeopardizing the viability of projects;
- Long transmission lines between project sites and load centres put a significant financial burden on the projects, particularly considering the ratio between line length and the power demand;
- Lack of technical expertise in undertaking hydropower projects among local contractors;
- Hinterland villages face the problem of clustered settlements with large distances among villages and even individual houses resulting in high cost for connection of households to the electricity supply.[5]

The country's vast hydropower potential needs strong de-risking efforts aimed at improving the attractiveness of hydropower projects, possibly bundling several projects together to channel development to a successful outcome.

References

1. World Bank (2017). *Guyana. Population, total*. Available from https://data.worldbank.org/indicator/SP.POP.TOTL?locations=GY

2. United Nations Food and Agriculture Organization (FAO) (2015). *Guyana.* Aquastat database. Available from www.fao.org/nr/water/aquastat/countries_regions
3. Encyclopaedia Britannica (2018). *Guyana*. Available from https://www.britannica.com/place/Guyana#ref26769
4. World Bank (2016). *Guyana. Access to electricity (% of population).* Available from https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=GY
5. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
6. Guyana Power and Light Incorporated (GPL) (2018). *Annual Report for 2017.* Available from http://www.gplinc.net/
7. Guyana Power and Light Incorporated (GPL) (2014). *Annual Report for 2013.* Available from http://www.gplinc.net/
8. Guyana Energy Agency (GEA) (2018). Internal data provided by authors
9. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
10. The National Energy Policy Committee (1994). *Energy Policy of Guyana.* Available from http://goinvest.gov.gy/wp-content/uploads/Energy-Policy-of-Guyana-94.pdf
11. Guyana Energy Agency (2015). *Hydro.* Available from https://gea.gov.gy/index.php?option=com_content&view=article&id=4&Itemid=108
12. Frankfurt School - UNEP Collaborating Centre for Climate & Sustainable Energy Finance (2012). *Case Study: The Guyana REDD-plus Investment Fund (GRIF).* Available from http://www.fs-unep-centre.org/
13. Government of Guyana (1998). *Electricity Sector Reform Act.* Available from http://goinvest.gov.gy/wp-content/uploads/cap5701.pdf
14. The Guyana office for investment (n.d.). *Official website.* Available from http://goinvest.gov.gy/

2.3.9

Paraguay

International Center on Small Hydro Power (ICSHP)

Key facts

Population	6,811,297[1]
Area	406,750 km[2]
Climate	The climate is sub-tropical in the Paraneña region and tropical in the Chaco region, with average temperatures of 22 °C. The winter season lasts from May to August, with July being the coldest month (17 °C). The summer season lasts from October to March, with January being the warmest month (29 °C). Daytime temperatures reaching 38 °C are common.[2]
Topography	Approximately two-thirds of the country are covered by the Gran Chaco, a flat tropical region extending into Bolivia and Argentina. The Paraná Plateau in the eastern region represents an extension of the Brazilian Plateau and varies in elevation from 50 metres to 760 metres. The Amambaí Mountains run along the border with Brazil, then turn and run eastwards as the Mbaracayú Mountains. The highest peak, Mount San Rafael at 850 metres, is located in the Cordillera de San Rafael in the south-east.[3]
Rain pattern	There are regional and seasonal variations in rainfall. The eastern region receives an average of 1,270 mm of rain annually, while some areas receive upwards of 1,800 mm. The Chaco region is considerably drier, with some areas receiving only 400 mm per annum.[2]
Hydrology	The Paraguay and Paraná Rivers are the two main watercourses in the country. They define most of the borders and their basins provide all of the drainage. The major tributaries entering the Paraguay River from the eastern region (such as the Apa, Aquidabán and Tebicuary Rivers) descend rapidly from their sources in the Paraná Plateau to the lower lands. The major tributaries of the Parana, which originate in the Paraguayan territory, are the Acaray, Monday, Piratiy and Carapá. All of these possess important hydroelectric potential.[2,3]

Electricity sector overview

Paraguay is a country with a wealth of unique natural energy, particularly hydropower, and is regarded as one of the largest exporters of energy and the largest exporter of hydroelectricity in the world. Despite this, the country has domestic supply issues due to the limited capacity of the transmission grid to transfer power from hydropower plants located in remote areas to the main load centre in the metropolitan area. However, under the 2014-2023 Power Sector Expansion Plan, the Government is intending to invest into an additional 2,833 km of line length, 9,215 MVA of transformer capacity and 19 substations between 2016 and 2023. [4]

The total installed capacity of Paraguay is approximately 8,835 MW (Figure 1). Only 24.94 MW is from thermal plants: Salto del Guairá (20.875 MW), Pedro J. Caballero (3 MW), Fuerte Olimpo (0.5 MW), Bahía Negra (0.565 MW).[5] Most of the capacity comes from the bi-nationally operated hydropower plants (HPPs). The Itaipú HPP, jointly operated with Brazil, provides 7,000 MW, whilst 1,600 MW are from the Yacyretá HPP, jointly owned with Argentina.[5] There is also the 210 MW Acaray HPP, which is solely Paraguayan owned.[6]

Total electricity generation in 2017 was 59,685 GWh, of which 58,726 GWh (98.3 per cent) was from the bi-national hydropower plants, 957.5 GWh (1.6 per cent) from the Acaray HPP and only 1.5 GWh (0.002 per cent) from thermal power plants (Figure 2).[7] Electricity generation per capita in Paraguay is one of the highest in the world (at approximately 9,000 MWh per year), however, only a fraction of this electricity is used domestically.[8] Most of the generated electricity is exported to Brazil and Argentina, roughly 73 per cent in 2017.[7]

Figure 1.
Installed electricity capacity by source in Paraguay (MW)

Source: ANDE[5,6]

Figure 2.
Annual electricity generation by source in Paraguay (GWh)

Source: Vice Ministry of Mines and Energy[7]

In 2017, domestic electricity supply in Paraguay was at 15,555 GWh, of which approximately 43 per cent was consumed by the residential sector, 20 per cent by the industrial sector, 18 per cent by the commercial sector, 15 per cent by the public sector and other types of consumers and 4 per cent for street lighting.[7] In 2017, hydropower accounted for 61 per cent of primary energy production, while the remaining 39 per cent was from biomass. In addition, due to a significant decrease (by 18.5 per cent) in hydroelectricity generation in 2017 compared to 2016, the country had to increase imports of petrol products. Electricity losses in 2017 stood at 25.7 per cent.[7]

The Administracion Nacional de Electricidad (ANDE) is a state-owned utility that controls the electricity market, including generation, transmission and distribution. ANDE operates all thermal power plants and the Acaray HPP and is also responsible for the share of Paraguay of the bi-national HPPs. ANDE operates the transmission and distribution network, in addition, there are also some private regional networks connected to the national grid.[9] As of 2016, the national electrification rate was 98 per cent, with access in rural areas at roughly 96 per cent.[10]

The tariffs for the electricity sector are determined by ANDE, as per Law 2199/03 (Article 16).[11] Tariffs vary depending on the type and volume of consumption (Table 1).[12]

Table 1.
Electricity tariffs in Paraguay

Type	*Tariff (PYG/kWh (US$/kWh))*
Residential	311.55-435.51 (0.052-0.073)
Industrial	404.97 (0.068)
Government	388.16 (0.065)
Street Lights	427.14-482.88 (0.071-0.081)
Other	406.00 (0.068)

Source: ANDE[12]

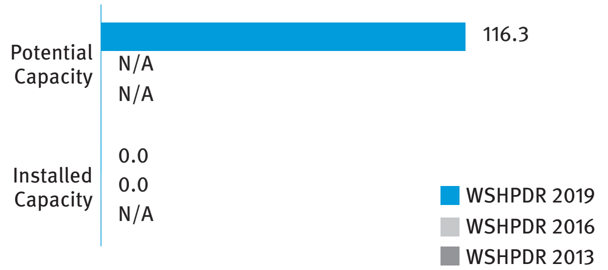
The Paraguayan electricity system is prone to high system losses, frequent blackouts and shortages during inclement weather, which can negatively affect commercial activities in the country. The main causes of the increasing inefficiency of the system are the insufficiently developed transmission network as well as the structure of the energy sector itself. The Vice Ministry of Mines and Energy decides the national energy strategy. However, this is often circumvented by the organizational and financial strength of ANDE. Moreover, there is little incentive for ANDE to address the issue of system-wide losses, as any surplus in operation is transferred to the Ministry of Finance.[9,13]

At the same time, the demand for electricity is expected to grow both in Paraguay and the neighbour countries it exports hydroelectricity to. Thus, domestic peak demand in 2020 is projected to reach 4,260-4,847 MW. Several new hydropower projects have been planned by ANDE to meet the increased demand. The largest of these projects is the Corpus Christi HPP, a joint project with Argentina that will have an installed capacity of 1,256 MW and is expected to be operational by 2030.[9,13] In 2018, ANDE also announced the plans to rehabilitate and modernize the Acaray HPP, which will include the addition of a third powerhouse with two 37.5 MW turbines.[14]

Small hydropower sector overview

The definition of small hydropower (SHP) in Paraguay is up to 50 MW. As of 2018, there were no small hydropower (SHP) plants in operation. While total SHP potential is unknown, based on the projects planned to be completed by 2025, it is possible to conclude that there is at least 116.3 MW of undeveloped potential.[15] Compared to the *World Small Hydropower Development Report (WSHPDR) 2016*, installed SHP capacity remained unchanged, while potential increased due to access to new data (Figure 3).

Figure 3.
Small hydropower capacities 2013/2016/2019 in Paraguay (MW)



Source: *WSHPDR 2016*,[9] ANDE[15]

Note: The comparison is between data from *WSHPDR 2016* and *WSHPDR 2019*.

Paraguay has an enormous hydropower potential estimated at 130 TWh annually, while technical and economically feasible potential is estimated at 101 TWh annually, which greatly exceeds the country's current installed capacity.[9,13] Under the 2016-2025 Generation Master Plan, there are plans to install 18 SHP plants across the country, which will allow freeing up the capacity of the Acaray HPP for backup generation and potentially export. The combined capacity of these projects is 116.3 MW.[15] Under this plan, SHP development is seen as a solution for providing access to electricity in a decentralized manner not requiring the expansion of the transmission network, thus, decreasing transmission losses and improving the reliability of the electricity system. The plan also recognizes the benefits of SHP for the communities, in particular the development of new skills among local population and the provision of favourable conditions for the development of local enterprises due to an improved access to electricity.[15]

Table 2.
Planned small hydropower projects in Paraguay

Name of the plant	*Installed capacity (MW)*	*Planned year of completion*
Jejui-3	2 x 2.70	2021
Jejui-2	2 x 5.00	2022
Jejui-1	2 x 3.50	2024
Tembey-1	2 x 1.80	2021
Tembey-3	2 x 1.80	2022
Capiibary-1	2 x 2.80	2022
Tembey-2	2 x 5.50	2023
Pirajui-1	2 x 4.30	2024
Ñacunday-2	2 x 2.15	2020
Carapá-2	2 x 2.15	2022
Ñacunday-1	2 x 4.00	2023
Carapá-1	2 x 9.50	2024
Itambey-1	2 x 2.50	2024
Ypané-5	2 x 2.50	2019
Ypané-2	2 x 2.10	2021
Ypané-3	2 x 2.10	2021
Ypané-4	2 x 2.15	2021
Ypané-1	2 x 1.60	2022
Total	**116.30**	

Source: ANDE[15]

The first small hydropower plant to be developed in Paraguay will be the SHP project on the Ypané River with a total capacity of some 14 MW. ANDE opened the bidding process for the construction, operation and maintenance of the plant a number of times in 2017-2018, however, was each time cancelled by ANDE due to the lack of a single bidder.[16,17,18]

Renewable energy policy

By the end of the year 2017 the Government of Paraguay was expected to approve the country's first law on renewable energy. According to the law project, the ANDE would be obliged to acquire at least 5 per cent of its total power from various renewable energy (RE) source, other than hydropower. The law was reportedly approved by the upper chamber of the Parliament and was subject to the review by the Senate, however, in October 2017 the project was rejected by the Government.[19] Nonetheless, the 2016-2025 Generation Master Plan foresees the promotion of RE technologies, particularly large- and small-scale hydropower, but also solar photovoltaics.[15]

ANDE was the monopoly controller of the electricity market until 2006, when Law 3009/06 was adopted. The law opened the market to independent power producers to generate and transport electricity for domestic consumption or export. The law applies to all RE resources with the exception of hydropower plants larger than 2 MW. Despite the opening of the market, only a handful of proposals have been submitted currently.[9]

For any new projects, Law 2009/06 is also applicable as it established that access to the grid is non-discriminatory. Environmental Impact Assessments (EIA) are required by Law 294/93. Meanwhile Law 352/94 regulates protected areas. Regarding solar energy, Law 3557 approved an EU project to provide solar PV to 45 centres, while Decree 6417 provided solar to 35 isolated communities.[9]

Barriers to small hydropower development

Paraguay has a great potential for both large and small hydropower. However, the development of SHP is particularly hindered by the institutional structure and the market conditions of the country's electricity sector, namely:

- Lack of incentives for ANDE to alter the current model of operation of the electricity system and the generation of electricity;
- Insufficient demand to incentivize independent power producers to enter the market.[9]

References

1. World Bank (2017). *Paraguay. Population, total.* Available from https://data.worldbank.org/indicator/SP.POP.TOTL?locations=PY
2. United Nations Food and Agriculture Organization (FAO) (2015). *Paraguay*. Available from www.fao.org
3. Encyclopaedia Britannica (2018). *Paraguay*. Available from https://www.britannica.com/place/Paraguay
4. Global Transmsission Report (2016). *Paraguay's Grid Development: Struggling to meet demand despite surplus capacity.* Available from http://www.globaltransmission.info/archive.php?id=26082
5. Administracion Nacional de Electricidad (ANDE) (n.d.). *Generación Hidráulica.* Available from http://www.ande.gov.py/generacion.php
6. Administracion Nacional de Electricidad (ANDE) (2013). *ANDE habilitó la Unidad 3 de la Usina de Acaray II.* Available from http://www.ande.gov.py/interna.php?id=1161#.W962mnpKjq0
7. Vice Ministry of Mines and Energy (2018). *Balance Energético Nacional 2017 en Términos de Energía Final.* Available from https://www.ssme.gov.py/vmme/pdf/balance2017/BEN2017.pdf
8. Vice Ministry of Mines and Energy (2017). *Electricidad – Generación.* Available from https://www.ssme.gov.py/vmme/index.php?option=com_content&view=article&id=1216&Itemid=603
9. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016.* United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
10. World Bank (2016). *Paraguay. Access to electricity (% of population).* Available from https://data.worldbank.org/

indicator/EG.ELC.ACCS.ZS?locations=PY
11. Latin American Energy Organization (OLADE) (2011). *Paraguay, Final Report*. Available from http://www.renenergyobservatory.org/uploads/media/Paraguay_Producto_1_and_2__Eng__05.pdf
12. Administracion Nacional de Electricidad (ANDE) (2017). *Pliego de Tarifas Nº 21 Aprobado por Decreto Nº 6904 del Poder Ejecutivo de la Nación de Fecha 10 de Marzo de 2017.* Available from http://www.ande.gov.py/docs/tarifas/PLIEGO21.pdf
13. Vale Columbia Center on Sustainable International Investment (2013). *Leveraging Paraguay's Hydropower for Sustainable Economic Development, Final Report*. Columbia University. Available from ccsi.columbia.edu/files/2013/11/Leveraging_Paraguays_Hydropower_for_Economic_Development.pdf
14. Ingram, E. (2018). *ANDE announces plans to overhaul 200-MW Acaray hydroelectric plant in Paraguay.* Hydroworld, 20 September 2018. Available from https://www.hydroworld.com/articles/2018/09/ande-announces-plans-to-overhaul-200-mw-acaray-hydroelectric-plant-in-paraguay.html
15. Administracion Nacional de Electricidad (ANDE) (2016). *Plan Maestro de Generación. Periodo: 2016-2025.* Available from http://www.ande.gov.py/documentos/plan_maestro/PM_2016_2025_Gen_Trans_Distrib_Telematica.pdf
16. Harris, M. (2017). *Paraguay's ANDE restarts bids for 10-MW Ypane River plant.* Hydroworld, 30 September 2017. Available from https://www.hydroworld.com/articles/2017/10/paraguay-s-ande-restarts-bids-for-10-mw-ypane-river-plant.html
17. ABC Color (2017). *La ANDE ya planea comprar energía de la central Ypané a partir de 2022.* ABC Color, 9 December 2017. Available from http://www.abc.com.py/edicion-impresa/economia/la-ande-ya-planea-comprar-energia-de-la-central-ypane-a-partir-de-2022-1656752.html
18. ABC Color (2018). *ANDE organiza audiencia pública para socializar proyecto del Ypané*. ABC Color, 13 March 2018. Available from http://www.abc.com.py/edicion-impresa/economia/ande-organiza-audiencia-publica-para-socializar-proyecto-del-ypane-1682992.html
19. Sánchez Molina, P. (2017). Paraguay veta las renovables. PV Magazine, 4 December 2017. Available from https://www.pv-magazine-latam.com/2017/12/04/paraguay-veta-las-renovables/

2.3.10

Peru

Jorge Reyes and Leo Guerrero, University of Piura; and International Center on Small Hydro Power (ICSHP)*

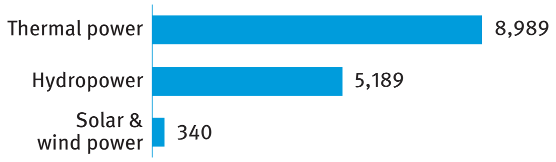
Key facts

Population	32,165,485[1]
Area	1,285,215 km[2]
Climate	Peru has diverse climates and microclimates, including 28 of the 32 world climates. Such a diversity is conditioned by the presence of the Andes Mountains, the cold Humbolt Current and El Niño. The temperature varies from below 0 °C to 40 °C.[2]
Topography	Peru is divided into three contrasting topographical regions: the coast, the highlands and the eastern rainforests, ranging in elevation from 0 metres on the coast to 6,768 metres in the highlands.[2]
Rain pattern	In the northern coast, the summer rainfall total rarely exceeds 200 mm, except during the severe El Niño events, which can provoke major flooding with precipitations higher than 4,000 mm. In the central and southern coasts, rainfall is scarce with a total range between 10 mm and 150 mm.[2]
Hydrology	The main rivers in Peru are the Amazon, Madre de Dios, Putumayo, Napo, Maranon, Huallaga and Apurimac.[2]

Electricity sector overview

The installed electrical capacity in Peru in 2016 was 14,518 MW. Approximately 62 per cent of the total installed capacity was derived from thermal power, 36 per cent from hydropower and 2 per cent was from solar and wind power (Figure 1).[3] Available capacity was, however, lower at 13,643 MW.[3] Total net electricity generation was estimated to be 51,700 GWh, with 47 per cent produced from hydropower (Figure 2).[3] Electricity consumption per capita stood at 1,446 kWh in 2016.[3]

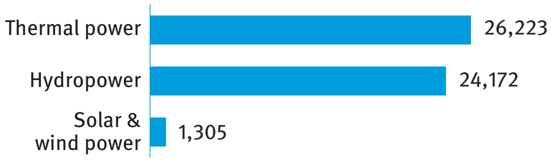
Figure 1.
Installed electricity capacity by source in Peru (MW)



Source: MINEM[3]

The electricity sector in Peru has been shaped by public sector investment and the active participation of the private sector. In the early 1990s, the Government issued a series of laws to promote private investment, highlighting the electricity sector as a national priority. The reform of the electricity sector started in 1992 with the promulgation of the Electricity Concessions Law. This law set the legal framework for the activities in the electricity sector. The general objective of this law is to promote a price system for greater economic efficiency by setting up a tariff for end-users. The tariff takes optimal usage of available energy resources into account. Generation, transmission and distribution utilities were unbundled as a result of this law. It also engaged the private sector in these commercial activities.[4,5]

Figure 2.
Annual electricity generation by source in Peru (GWh)



Source: MINEM[3]

In 2006, the Law for Efficient Generation Development came into force to complement the Electricity Concessions Law. The Law for Efficient Generation Development aims to guarantee efficient electricity generation, reducing the vulnerability of the Peruvian electrical system to price volatility and long blackout periods. It also provides the assurance of a competitive electrical tariff to consumers. In addition, it establishes two new different types of transmission systems, one for supplementary transmission and one for guaranteed transmission.[5]

Studies have shown a strong correlation between poverty levels and access to basic services including electricity. The Government of Peru has been making significant efforts to raise access to electricity in rural areas under its social inclusion strategies. In this regard, renewable energy (RE) technologies (especially solar, small hydropower and biomass) could play an important role in satisfying energy requirements in rural

* *WSHPDR 2016* updated by ICSHP

Peru.[6] The sustainable rates of economic growth over the period 2006-2016 had a positive impact on poverty reduction and provided for a great dynamism in both public and private investment. In 2016, private investment in the power sector constituted 89 per cent of total investments, while the Government invested 11 per cent. Most of investment in the sector concentrated in the generation subsector. The rate of per capita consumption being lower than average across Latin America shows that there is still space for more investment to be made into the development of the sector.[3]

The Peruvian electricity market has matched the country's economic growth and development. According to the Ministry of Energy and Mines (MINEM), the total installed capacity increased by 134 per cent between 2005 and 2016.[3,7] Demand has increased rapidly, with maximum demand having reached 6,937 MW in 2016, compared to 3,580 MW in 2006.[3] At the same time, the expansion of grid infrastructure has not matched the power demand requirements. This means that transmission is at present operating almost at maximum capacity, particularly in the country's southern and northern corridors. This adds to the challenges of raising power generating capacity in these areas, which are expected to become the new poles of development. To relieve this situation, investments in grid infrastructure are now under way. While almost all regions are connected to the National Interconnected System (SEIN), there is a clear heterogeneity in the regional electricity market. This situation is explained by the differences in the availability of resources, such as watersheds usable for electricity generation or access to pipelines transporting natural gas, the presence of SEIN transmission networks, location and heading of the main economic activities, population density or the number of customers, among others.[5]

The central part of the country has advantages in terms of the aforementioned criteria. In this part of the country, sector development focuses largely on the installed capacity of hydropower and thermal power efficient generation (Camisea natural gas). In particular, in Lima region the installed capacity in 2016 was 4,864 MW, in Moquegua 1,562 MW and in Huancavelica 1,539 MW.[3] In contrast, the regions where the main economic activities take place in remote areas, such as mining in the Sierra and exploitation of hydrocarbons in the jungle, have a greater presence of auto-generation units.[5] These differences are also expressed in consumption. For example, in 2016 Lima accounted for 17,027 GWh of total sales of electricity, including 11,500 GWh of sales to regulated customers and 5,527 GWh to free customers.[3] Regions with major mining and industrial operations, namely Arequipa, Ica, Moquegua and Ancash, have a high concentration of free customers outside the capital.[3]

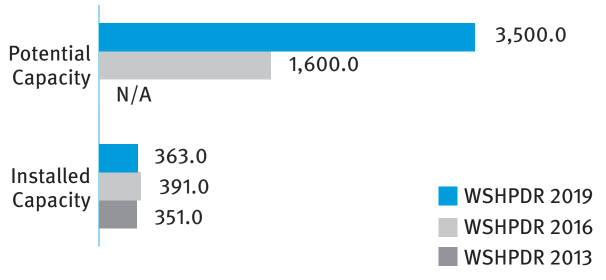
The Government regulates transmission and distribution tariffs. In 2016, prices for electricity ranged from 0.066 US$/kWh to 0.099 US$/kWh. These tariffs vary across the economic sectors.[3]

Peru has a total electrification rate of 94.9 per cent and a rural electrification rate of 75.6 per cent.[8] The National Rural Electrification Plan 2013-2022 set the target to provide access to electricity to 6.2 million people by 2022. Efforts are being made to increase access to electricity via auctions for solar photovoltaic systems, grid extension, mini-grids with hydropower, solar and wind power.[5,6]

Small hydropower sector overview

Small hydropower (SHP) is defined in Peru as plants with capacity less than 20 MW. In 2016, the Ministry of Energy and Mines completed an assessment of the country's hydropower potential and compiled a portfolio listing 571 potential projects. Out of these, 380 are below 20 MW with a combined capacity of 3,311 MW.[9] The total installed capacity of all SHP plants up to 20 MW as of October 2018 was 362.9 MW.[10,11,12] Given that it is problematic to identify which of the listed sites were developed between 2016 and 2018, it could be assumed that total SHP potential in Peru is at least 3,500 MW. Compared to the *World Small Hydropower Development Report (WSHPDR) 2016*, installed capacity up to 20 MW decreased by 7 per cent, which is due to access to more accurate data. The potential capacity more than doubled (Figure 3).

Figure 3.
Small hydropower capacities 2013/2016/2019 in Peru (MW)



Source: *WSHPDR 2016*,[5] MINEM,[9] Osinergmin,[10,11,12] *WSHPDR 2013*[13]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

MINEM, supported by the Advisory Committee, set a goal of preparing a proposal to institutionalize the process of energy planning in Peru. MINEM proposed three central hypotheses. First, it is considered that the national economy will grow by an average 4.5 per cent annually, and in a more optimistic scenario by 6.5 per cent. This is a situation that would confirm that the reserves and infrastructure are sufficient to continue to endure high rates of growth. Secondly, it is postulated that the level of energy prices in the domestic market will follow the trends in global energy prices, with the exception of gas. The price will reflect current contractual conditions and incorporate more lots with prices to match the offer and domestic demand.[5,6] Thirdly, MINEM emphasized the availability of resources, based on the fact that currently there are untapped reserves of hydropower, natural gas and non-conventional RE, all of which are considered suitable and sustainable for supporting economic growth.[5,7]

The most fundamental constraint to developing the country's hydropower potential has been the low tariff faced by generators, which is a consequence of the low domestic price of natural gas. Almost all new power generation installed in Peru during the last decade has been based on low priced natural gas from the Camisea Field. The price of Camisea gas delivered to plants near Lima is estimated at US$2.15 per BTU, which means an average price for gas-based generation of approximately US$0.035/kWh. Given that Peru will shortly become a liquefied natural gas (LNG) exporter, the opportunity cost of natural gas is now linked to international prices.[5,14]

Development of SHP has not been financially viable because the financial cost of generation was set by the cost of gas-based generation at a lower price for natural gas from Camisea. At an average price for gas-based generation of US$0.035/kWh, a 17.5 per cent financial rate of return (FIRR) on equity, a 10-year loan period and a 70 per cent load factor, the maximum capital cost that is financially viable for a hydropower project is approximately US$850/kW. When carbon finance and increasing cost of oil are taken into consideration, the allowable capital costs increase to approximately US$1,000/kW. Nevertheless, greenfield SHP projects cannot be built at such low capital costs. Unlocking the significant potential of SHP in Peru would require either the removal of the low price for natural gas from Camisea or a preferential tariff for SHP that reflects the economic opportunity cost of gas powered generation. Using a generation price based on the economic opportunity cost of gas generation of US$0.056/kWh and the same assumptions for FIRR, loan tenor and load factor, the allowable capital cost for SHP increases to US$1.4/kW. This is a level that would make many SHP plants financially viable in Peru, even with recent increases in hydropower construction costs.[5,15]

Renewable energy policy

The regulatory framework for the promotion of renewable energy has evolved since the enactment of the Electricity Concessions Law and its Regulations (1993, 1994), which created the electricity market and set its institutional arrangement. The Law on Efficient Generation (2006) promotes long tenders and contract terms as a means to support investment in large-scale generation (large hydropower and other conventional technologies). Legislative Decree No. 1002 (2008) declares, out of national interest and public necessity, the development of electricity generation from renewable energy resources (RER).[16] It establishes as a national priority the promotion of renewable energy sources, defining RER as the sources of non-conventional renewable energy – solar, wind, geothermal, biomass and hydropower up to 20 MW (hydropower RER).[5]

The Government promotes electricity sales of RER through auctions, setting the targets for each source of renewable energy generation. The main incentives offered are priority access to the office of System Economic Operation Committee (COES) and purchase of energy produced, priority access to transmission and distribution networks, and stable long-term rates determined by auction.[17] Auction Bases are approved by the Ministry of Energy and Mines; the Supervisory Agency for Investment in Energy and Mining (Osinergmin) leads the auction, fixes the maximum prices and determines the premiums through annual assessments.[5]

The main problems with RE resources is that the plants that operate with such technologies can create individual ecological problems. Additionally, there are a number of drawbacks that limit their economic cost competitiveness. These include:

- High investment costs: The capital cost for the technology is significant, while wind and solar power are becoming more competitive;
- Variability: Solar and wind power are unpredictable and cannot be dispatched, thus exhibit a low load factor.[5,7]

Legislation on small hydropower

It has been difficult to attract financial support for green energy projects. To rectify this, the MINEM approved some benefits for SHP projects under 10 MW installed capacity:

- All of the permitting process is carried out at the regional level with local authorities, where the project is located
- No Environmental Impact Assessment (EIA) is required. It is sufficient to file a non-environmental impact commitment document.[5,7]

The benefits of SHP projects in development and under construction are such that even some of the bigger power generation companies are investing in them in Peru. In some cases, larger companies even buy them as greenfield projects at the permitting stage or by acquiring hydropower plants in production. They proceed to invest additional funds, earmarked for improvements. In some cases, water storage facilities are added to the projects to enhance production. This is done without altering water use permits and by seeking support from the local stakeholders, who have already seen first-hand the benefits of having a local power plant operating and know that they can also benefit from the water regulation facility.[5,18]

Barriers to small hydropower development

Peru is rich in RE resources such as solar, hydropower, biomass, biogas, wind, and geothermal power, but only a small fraction of this potential is currently used. While investment in the RE sector has seen an increase, there are some barriers to the development of new RE projects, including SHP:

- Investment costs: All have different costs and depend on technology and resources.
- Operation and maintenance costs: All energy resources require moderate human resources training.
- Transport and construction infrastructure for most energy resources is limited.
- Environmental: Most RE projects have at least minimal to moderate environmental impact during the construction phase.
- Financial: Bankers' limited knowledge of the RE market

and profitability, credit officers' limited knowledge about RE project evaluation and regulations. Banks may need external technical support to assess RE investment projects and technical assistance component is required to credit lines.[5,19]

References

1. World Bank (2017). *Population, total.* Available from https://data.worldbank.org/indicator/SP.POP.TOTL
2. United Nations Food and Agriculture Organization (FAO) (2015). *Peru*. Aquastat database. Available from www.fao.org/nr/water/aquastat/countries_regions
3. Ministry of Energy and Mines (MINEM) (2018). Anuario Ejecutive de Electricidad 2016. Available from https://www.gob.pe/institucion/minem/informes-publicaciones/112025-anuario-ejecutivo-de-electricidad-2016
4. Gamboa, C., & Cueto, V. (n.d.). Hidroeléctricas y conflicto sociales: Recomendaciones para una mejor gestión ambiental. Matriz energética en el Perú y energía renovables, 72
5. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
6. International Renewable Energy Agency (2014). *Renewable Readiness Assessment 2014*. IRENA. Available from http://www.irena.org/DocumentDownloads/Publications/RRA_Peru.pdf
7. Ministerio de Energía y Minas (2014). *Anuario Ejecutivo de electricidad 2013*. Lima.
8. World Bank (2014). *Access to electricity (% of population).* Available from https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS
9. Ministerio de Energía y Minas (MINEM)(n.d.). *Portafolio de Proyectos Hidroeléctricos*. Available from http://mapas.minem.gob.pe/MAP_HIDROELECTRICO/
10. Supervisory Agency for Investment in Energy and Mining (Osinergmin) (2018). *Generación Eléctrica a Ingresar al SEIN (Periodo: 2013-2023).* Available from http://www.osinergmin.gob.pe/seccion/centro_documental/electricidad/Documentos/PROYECTOS%20GFE/Generaci%C3%B3n/Proyectos_GENERACION_proyecci%C3%B3n.pdf
11. Supervisory Agency for Investment in Energy and Mining (Osinergmin) (2018). *Supervisión de Contratos de Proyectos de Generación y Transmisión de Energía Eléctrica en Operación.* Available from http://www.osinergmin.gob.pe/empresas/electricidad/proyectos/publicaciones
12. Supervisory Agency for Investment in Energy and Mining (Osinergmin) (2018). *Centrales de Generación Eléctrica – en Operación.* Available from http://www.osinergmin.gob.pe/seccion/centro_documental/electricidad/Documentos/PROYECTOS%20GFE/Generaci%C3%B3n/2-EN-OPERACION.pdf
13. LIU, H., Masera, D. and Esser, L., eds. (2013). World Small Hydropower Development Report 2013. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
14. Meier, P., Zolezzi, E., Bogach, S., Uir, T., & Bazex, K. (2011). *Peru Opportunities and Challenges of Small Hydropower Development.* The World Bank Group, International Bank for Reconstruction and Development, Energy Sector Management Assistance Program
15. Mendiola, A., Aguirre, C., Agular, O., Castillo, S., Giglio, G., & Maldonado, W. (2012). Proyectos de generación eléctrica en el Perú ¿Centrales hidroeléctricas o centrales térmicas? Lima, Universidad ESAN
16. Ministerio de Energía y Minas (2014). *Plan Energético Nacional 2014-2025*. Lima
17. Ministerio de Energía y Minas (2015*). Evolución de indicadores del sector eléctrico 1995-2014*. Lima
18. Harmon, J. (2013). The Latin American Energy Deview. Available from MIni-Hydro in Peru: http://www.lacreview.com/2014/04/jharmonlacer/mini-hydro-in-peru/
19. Vera Tudela, R., Paredes, C., & Defilippi, E. (2013). *Mercado eléctrico en el Perú-Balance de corto plazo y agenda pendiente.* Universidad de San Martín de Porres, Lima

2.3.11 Suriname

International Center on Small Hydro Power (ICSHP)

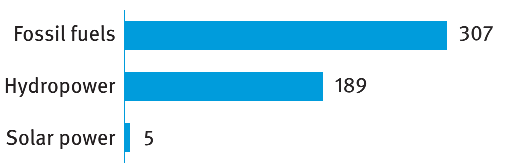
Key facts

Population	563,000 [1]
Area	163,820 km² [2]
Climate	Suriname has a tropical climate with dry and rainy seasons. As it lies outside the hurricane zone, the most extreme weather condition that occurs is heavy showers.[3] The temperature is temperate, with the lowest average temperature in January at 25 °C and the highest in October at 27 °C.[4] The humidity in the country is high at 70 to 90 per cent, and the country suffers the effects of El Niño, a current of warm water that periodically flows along the western coast of South America.[5]
Topography	Suriname is bordered by the Atlantic Ocean, French Guiana, Brazil and Guyana, and around 94 per cent of its territory is covered by forest.[7] Suriname can be divided into four ecological zones, namely the Young Coastal Plain (at sea level), the Old Coastal Plain (ranging from 0 to 10 metres above sea level), the Savannah (at 10 to 100 metres above sea level) and the Residual Uplands, with hills and mountains up to 1,230 metres above sea level.[5]
Rain pattern	There are two rainy seasons in Suriname, one of which occurs between December and January, and the other occurs between April and July.[3] Rainfall is highest in May at 376.8 mm and lowest in October at 56.8 mm. The average annual rainfall of the country is about 2,380 mm.[4]
Hydrology	There are seven major rivers in Suriname which drain northwards towards the Atlantic Ocean. These are the Maroni, Corentyne, Commewijne, Suriname, Saramacca, Coppename and the Nickerie. There are no rivers that cross into or out of Suriname. The rivers mentioned are on the border of the country but not considered to be border rivers, where the entire flow of the rivers is considered to be generated in both Suriname (50 per cent) and the respective border country (50 per cent). Nani Lake is the only natural fresh water lake, with total dam capacity estimated at 20 km³. Brokopondo Lake is the largest lake in the country covering 1,560 km². Swamps, which are characterized by stagnant water, dense tropical forest and large amounts of decaying vegetation, cover about 60 per cent of the Coastal Plains.[5]

Electricity sector overview

In 2015, the total electricity generation in Suriname was 2,258 GWh, where 902 GWh (40 per cent) was generated from oil and 1,356 GWh was generated from hydropower (60 per cent).[6] In 2016, the total installed capacity was 501 MW. The country's energy mix consisted of 307 MW (61 per cent) from fossil fuels, 189 MW (38 per cent) from hydropower and 5 MW (1 per cent) from solar power (Figure 1).[9,10] The 189 MW comes from the Afobaka hydropower plant which is owned by Surlalco, a private mining company.[12]

Figure 1.
Installed electricty capacity by source in Suriname (MW)



Source: World Energy Council,[9] United Nations Statistics Division[10]

The electrification rate in 2015 was about 85 per cent. However this figure is likely to have increased as projected energy demand was 500 MW and installed capacity is already at 501 MW.[7]

Losses from generation, in 2015, amounted to 242 GWh. This was 11 per cent of the total electricity production. With the 2012-2016 growth rate of the power demand of 6 per cent annualy , measures for the increased efficiency need to be considered. The Republic of Suriname has estimated that this would require financing at approximately US$ 485 million.[7]

Before the implementation of the 2016 Electricity Act, average retail electricity tariff in Suriname was 0.04 US$/kWh. This was one of the lowest tariffs in Latin America and the Caribbean and was supported by Government subsidies. The details of the average tariff for each type of consumer are given in Table 1.

In villages along the rivers in the Hinterland, diesel generators could be (partly) replaced by establishing micro-hydropower stations and/or in combination with solar photovoltaic systems however, the high set-up costs create barriers to the implementation of these technologies in these sparsely populated rural areas.[11]

Table 1.
Average electricity tariffs by consumer type in Suriname

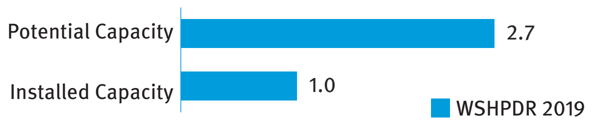
Type of consumer	*Average tariff (US$/kWh)*
Commercial	0.08
Industrial	0.09
Average retail price	0.04

Source: Climatescope[12]

Small hydropower sector overview

There is no official country definition for small hydropower (SHP). In this report SHP is defined as the plants with a capacity of less than 10 MW. The total potential capacity of hydropower currently stands at 2,590 MW, with SHP potential estimated at least at 2.7 MW based on the planned plants (very likely to be more).[11,13] Plans for achieving at least 2.7 MW of SHP installed capacity were included in the initial plan of the Development of Renewable Energy, Energy Efficiency and Electrification of Suriname Project. However, due to budget limitations, the Ministry of Natural Resources submitted a restructuring proposal on April 7, 2017, and it was agreed that the Rural Small Hydro Project section would be cancelled.[14] Figure 2 shows the estimated installed capacity for SHP in Suriname and as it is a new country in the *World Small Hydro Power Development Report 2019 (WSHPDR 2019)*, there are no comparisons with the previous reports.

Figure 2.
Small hydropower capacities in Suriname (MW)



Source: IRENA,[15] IADB[14]

Note: Suriname is a new country introduced in the *WSHPDR 2019*.

Renewable energy policy

In March 2016, the Government of Suriname set out to improve the technical and financial situation of its power sector through the enactment of the Electricity Act. This is the first comprehensive energy related act adopted in the country.[16] The aim of this Act was to create an energy regulatory authority, deal with the issue of overly low electricity tariffs by stating that subsidies must be reduced in order to improve energy efficiency and to attract more investment into renewable energy.[12,16,18]

The Act creates the Energy Authority of Suriname (EAS), which oversees the country's energy sector. This is done mainly through the publication of an Electricity Sector Plan (ESP). The state utility Energie Bedrijven Suriname (EBS) is mandated to hold renewable energy tenders under the supervision of the EAS.[16] Furthermore, its net metering system requires that the surplus electricity that is generated by retail electricity consumers that own renewable energy generation systems can feed it back to the national grid. This, therefore, reduces the consumers' consumption level by the amount generated and fed back to the grid. This amount cannot exceed total consumption for the year.[17]

The Electricity Act introduces Suriname's first legislation in favour of renewables, in particular wind and solar energy. The Act stipulates that, the utility owned electricity company, Energie Bedrijven Suriname (EBS), is obliged to purchase all electricity produced by the wind and solar plants, as well as electricity generated by the winning projects. Bid winners are required to go through the Ministry of Energy Affairs to construct, commission and operate their projects.[16]

Barriers to small hydropower development

The following barriers are particularly critical for SHP development in Suriname:

- In general, the low electricity tariffs are a major barrier to renewable energy development. Although, the Electricity Act has started to deal with this issue, it will take some time before it has an impact.[12]
- The lack of funding is another issue as seen from the Development of Renewable Energy, Energy Efficiency and Electrification of Suriname Project, where there was planned hydropower but lack of funding led to the cancellation of that part of the project.[14]

References

1. United Nations, Department of Economic and Social Affairs, Population Division. *World Population Prospects: The 2017 Revision, Key Findings and Advance Tables. Working Paper No. ESA/P/WP/248.* New York: United Nations, 2017.
2. The World Bank Group (2017). World Development Indicators. *DataBank.* Available from Accessed January 16, 2018. Available from http://databank.worldbank.org/data/reports.aspx?source=2&country=PRK. Accessed 22 May 2018.
3. World Weather and Climate Information. *Climate: Average Monthly Weather in Pyong Yang, North Korea.* 2016. Available from https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine-in-Suriname. Accessed 22 May 2018.
4. The World Bank Group (2018).Average Monthly Temperature and Rainfal for Surjiname from 1901-2015. *Climate Change Knowledge Portal.* Available from http://sdwebx.worldbank.org/climateportal/index.cfm?page=country_historical_climate&ThisRegion=Latin%20America&ThisCCode=SUR. Accessed 22 May 2018.
5. FAO. 2016. *AQUASTAT website.* Food and Agriculture Organization of the United Nations (FAO). Available from http://www.fao.org/nr/water/aquastat/countries_regions/SUR/index.stm.

Accessed 22 May 2018.
6. OECD/IEA (2018). Suriname: Electricity and Heat for 2015. Available from https://www.iea.org/statistics/statisticssearch/report/?year=2015&country=SURINAME&product=ElectricityandHeat. Accessed on 22 May 2018.
7. Government of Suriname. United Nations Framework Convention on Climate Change (2015). Intended National Contribution from the Republic of Suriname. 30 September. Available from http://www4.unfccc.int/submissions/INDC/Published%20Documents/Suriname/1/INDC-2-Suriname%20300915.pdf
8. United Nations Statistics Division (2018). Area: Suriname. *SDG Indicators.* Available from https://unstats.un.org/sdgs/indicators/database/?area=SUR. Accessed on 6 June 2018.
9. World Energy council (2018). Data. Energy Resources. Available from https://www.worldenergy.org/data/resources/country/suriname/. Accessed on 8 June 2018.
10. United Nations Statistics Division (2018). Net installed capacity of electricity plants — by type. *2015 Energy Statistics Yearbook.* Available from https://unstats.un.org/unsd/energy/yearbook/2015/t30.pdf. Accessed on 8 June 2018.
11. Republic of Suriname, Ministry of Labor, Technological Development and Environment (2005). First National Communication under the United Nations Framework Convention on Climate Change. National (UNFCCC). Institute for Encironment and Development in Suriname (NIMOS). Available from http://www.nimos.org/pdf/documenten/Klimaatrapport.pdf. Accessed on 11 June 2018.
12. Climatescope (2017). Country: Suriname. Available from http://global-climatescope.org/en/country/suriname/#/enabling-framework. Accessed on 1 June 2018.
13. Republic of Suriname, Ministry of Natural Resources (2011). Project Identification Form for Development of Renewable Energy, Energy Efficiency and Electrification of Suriname. Available from https://www.thegef.org/sites/default/files/project_documents/8-23-2011%2520ID4497%2520rev%2520PIF_0.pdf. Accessed on 1 June 2018.
14. Inter-American Development Bank (IADB) (2017) PMR Operational Report. IDB Improving Lives, October 4. Available from http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=EZSHARE-522669563-1151. Accessed on 14 June 2018.
15. IRENA (2017). Renewable Energy Statistics 2017. The International Renewable Energy Agency, Abu Dhabi.
16. Climatescope (2017). Ploicies: Suriname Renewable Energy Tenders. Available from http://global-climatescope.org/en/policies/#/policy/5433. Accessed on 15 June 2018.
17. Climatescope (2017). Ploicies: Suriname Net Meetering. Available from http://global-climatescope.org/en/policies/#/policy/5427. Accessed on 15 June 2018.
18. Climatescope (2017). Ploicies: Suriname Renewable Energy Priority Dispatch. Available from http://global-climatescope.org/en/policies/#/policy/5429. Accessed on 15 June 2018.

2.3.12 Uruguay

Martin Scarone, Ministry of Industry, Energy and Mining (MIEM)

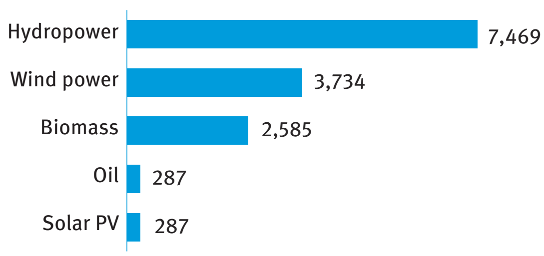
Key facts

Population	3,432,000 [1]
Area	176,215 km[2]
Climate	Uruguay has a temperate climate with cold winters (June to September) and hot summers (November to March). The average temperature in January is 24 °C. In July it is estimated at 10 °C. Maximum temperatures can reach between 28 °C and 33 °C, while the minimum ones vary from 6 °C to 9 °C.[1]
Topography	The landscape features mostly rolling plains and low hill ranges (cuchillas) with fertile coastal lowland. The highest elevation is roughly 520 metres. The north-west of the country is the most diverse, characterized by a multitude of hills, valleys and plains.[1]
Rain pattern	Uruguay has a rainy climate without a dry season. The rains are characterized by their extreme irregularity and annual variability. The annual precipitation varies between 1,100 mm in the south of the country and 1,600 mm in the north.[1]
Hydrology	Uruguay is surrounded by rivers on three sides. In the north, the Cuareim River forms its border with Brazil for more than 280 km. On the southern border is the Río de la Plata, the large estuary formed by the union of the Uruguay and Paraná Rivers. The Uruguay River, from which the country took its name, forms the western boundary and is by far the largest and most picturesque of the country's rivers.[1,14]

Electricity sector overview

In 2017, the electricity generated in Uruguay was 14,364 GWh. Of the total generated, 7,469 GWh came from hydropower plants, 3,734 GWh from wind power, 2,585 GWh from biomass, 287 GWh from oil resources and 287 from solar PV (Figure 1).[11] Thus in 2017 98 per cent of the electricity production in Uruguay was based on renewable energy. In 2017, the Global Competitiveness Index of the World Economic Forum ranked Uruguay first in the Latin American region for its quality of electricity supply. Therefore the reliability of the country's electricity system is high.[15]

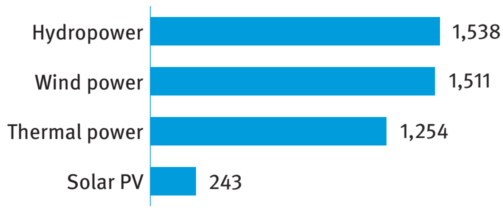
Figure 1.
Annual electricity generation by source in Uruguay (GWh)



Source: MIEM[11]

At the end of 2017, the total installed capacity of electric power plants was 4,546 MW. The total installed capacity of hydropower plants was 1,538 MW, 1,254 MW of thermal plants that run on fossils fuels and biomass, 1,511 MW of wind energy and 243 MW of solar energy.[11] Regarding the installed capacity by energy source, the most significant share in 2017 corresponded to renewable energy with over 82 per cent (hydropower, biomass, wind, solar), whereas non-renewable energy accounted for just under 18 per cent of total capacity (gas oil, fuel oil, gas natural).[11]

Figure 2.
Installed electricity capacity by source in Uruguay (MW)



Source: MIEM[11]

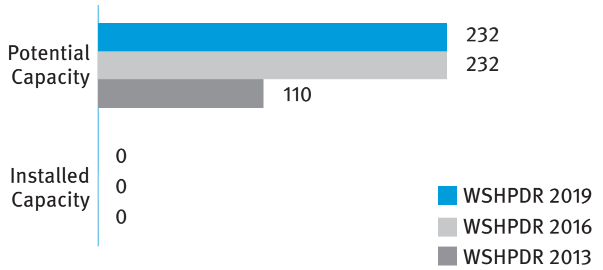
The recent reforms of Uruguay's energy sector have received positive feedback from both the World Bank and the Economic Commission for Latin America and the Caribbean and was named among the leading country in renewable energy. The success is due to a strong partnership between the public and the private sectors as well as a supportive regulatory system. The consumption of energy in 2017 was approximately 10,784 GWh.[10] The electric grid in Uruguay consists of 770 km of 500 kV lines that are connected from Salto Grande through the Rincon del Bonte dam to the main consumer centre in Montevideo. The national grid also includes a branch to San Carlos City, located in the south-east of the country. There are 3,549 km of 150 kV lines connecting the power generation plants with almost all the major cities and main load centres.[3,14]

In Uruguay, electricity generation is open and every generator can connect with the public electric grid. Private generation companies must sign contracts with the electricity utility Administración Nacional de Usinas y Trasmisiones Eléctricas (UTE) or sell at the spot price. UTE is the only distribution and transmission operator in Uruguay. The electrification rate in Uruguay is 99.7 per cent.[12] The average household electricity tariff is US$ 0.19 for 600 kWh per month.[4]

Small hydropower sector overview

In Uruguay small hydropower plants (SHP) are defined as having an installed capacity of up to 50 MW. Mini-hydropower is defined as palnts between 100 kW and 1,000 kW, micro-hydropower is defined as less than 100 kW and pico-hydropower as less than 5 kW.[9] The SHP installed capacity remains 0 MW, while potential remains at 232 MW.[14,15]

Figure 3.
Small hydropower capacities 2013/2016/2019 in Uruguay (MW)



Source: *WSHPDR 2013*,[8] *WSHPDR 2016*,[14] WEF[15]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

Regarding SHP potential, there are three kinds of sectors that have been studied: SHP sites only for generation, SHP sites that can be added to a dam used for irrigation and hydropower sites that can be added to a dam that can be used for irrigation but have not yet been developed.

In the case of SHP sites only for generation, the study was carried in all the rivers except for the rivers on the borders and the Black River. Up to 70 feasible sites were identified, all of which would not cause environmental damage or droughts in the surrounding areas. These 70 sites have a potential capacity of 232 MW. Of these 70 sites, five were selected in order to study installed capacity, energy generation, environmental impact and economic and financial feasibility. Of these five projects, only the projects of Arerengua, Arapey and Yerbal were determined to be economically feasible (including the price of the land) with the energy prices that are being paid currently (Table 1).[7,14]

Table 1.
Studied potential small hydropower sites in Uruguay

River	*Potential capacity (MW)*	*Capacity factor (per cent)*	*Estimated energy generation per year (MWh)*
Arapey 80 m	7.00	62	38.69
Arapey 130 m	3.70	62	19.69
Yerbal 88 m	2.60	74	16.59
Arerungua 90 m	8.90	68	52.35

Source: IMFIA,[7] *WSHPDR 2016*[14]

From the more of 1,331 irrigation dams already built in Uruguay, 20 dams were selected to carry out a generation viability studies. Moreover, economic and technical feasibility studies were carried out. The average capacity for each dam is 100 kW.[14]

Renewable energy policy

In the Uruguayan 2005-2030 National Energy Policy, the Government has set a renewable energy goal of 50 per cent native renewable sources in its primary energy matrix by 2015. The target set has not only been achieved, but also considerably surpassed. Among other measures to accomplish this, non-traditional renewable energy sources (wind, biomass residues) will contribute 15 per cent of the total generation. It has also set up the target of reaching 90 per cent of renewable energy in its electric matrix by 2030.[4,14] According to the official statistics, Uruguay achieved 98 per cent renewable energy in its electric matrix in 2017.[11]

In 2007, the Government of Uruguay offered 20 MW to be added to the grid from SHP, but no private investors applied. The Government still plans to develop SHP to promote rural development and to increase the number of irrigation dams. Article 47 of the Uruguayan Constitution outlines the utilization of water and defines the right to water and sanitation as a fundamental human right. In accordance with the requirements established by Law No. 16466 of Environmental Impact (1994) and enabling regulations established in regulatory code No. 349/005 (Evaluation of Environmental Impact), an environmental permit must be requested for the hydropower projects with capacities exceeding 10 MW or water flows greater than 0.5 m^3/s. Law No. 16 906 on the Promotion and Protection of Investments provides a framework for encouraging investments in the country, upon approval by the designated commission. Enabling regulation No. 354/009 promotes the generation of electricity from non-traditional renewable energy sources and grants the exemption of a significant percentage of the income tax for electric generating companies at the start of business, with subsequent reductions in the following years. Decree 2/2012 establishes tax benefits that may be granted (income tax deduction according to amount of investment, tax exemptions, VAT returns).[6, 14]

Barriers to small hydropower development

There is a significant potential for SHP in Uruguay. However, the barriers hindering hydropower and SHP development in the country are outlined below.

- A fundamental gap of experience and knowledge between planning and implementation, operation and maintenance of SHP;
- Insufficient information on the approval process for SHP projects;
- Risk with lengthy investment periods and uncertainty with regards to the success of constructing SHP plants;
- An untested national market for renewable, and the tendency of investors to instead choose other larger and more established markets such as Brazil;[17]
- Uruguay's large plains are greatly suited to building solar and wind power facilities. Growing interest in these other renewable resources lowers the likelihood of implementing SHP projects in the region;[18]
- Socio-economic and environmental assessments of SHP projects might be too costly and there are currentlylimited financial and tariff incentives in the sector.[14]

References

1. United Nations Food and Agriculture Organization (FAO) (2017). *Uruguay*. Aquastat database. Available from www.fao.org/nr/water/aquastat/countries_regions.
2. Instituto Nacional de Estadistica (n.d.). *Energia, Gas y Agua*. Available from www.ine.gub.uy/web/guest/energia-gas-y-agua.
3. International Energy Agency (IEA) (2015). Uruguay: Electricity and Heat for 2015, Available from http://www.iea.org/statistics/ .
4. Uruguay XXI Investment and Export Promotion Agency (2014). *Renewable energy, Investment opportunities, August 2014*. Available from http://www.uruguayxxi.gub.uy/invest/wp-content/uploads/sites/4/2014/07/Renewable-energy-August-2014.pdf.
5. UTE (2015). *Pliego Tarifario*. Available from http://portal.ute.com.uy/sites/default/files/documents/files/Pliego%20Tarifario%20enero%202015.pdf.
6. Uruguay, Ministerio de Industria, Energia y Mineria (n.d.). Available from http://www.dne.gub.uy/web/energia/principal/filtros.
7. Faculty of Engineering, University of the Republic (IMFIA) (2013). *Generación Hidroeléctrica en pequeña escala.* Agencia Nacional de Investigacion e Innovacion (ANII). Available from http://www.dne.gub.uy/documents/48237/4406457/PCH%20Generacion.pdf.
8. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from: www.smallhydroworld.org. Accessed 28 April 2018
9. Uruguay, Ministerio de Industria, Energía y Minería (2013). *Pequeñas Centrales Hidroeléctricas (PCH).* Available from http://www.dne.gub.uy/web/energia/-/pequenas-centrales-hidroelectricas-pch-.
10. Administración del Mercado Eléctrico (ADME) (2017). Annual Report 2017. Available from http://adme.com.uy/db-docs/Docs_secciones/nid_526/InformeAnual2017.pdf
11. Ministry of Industry, Energy and Mines (MIEM) (2017). Uruguay National Energy Balance. Available from http://www.miem.gub.uy/sites/default/files/presentacion_ben2017.pdf . Official websitehttp://www.ben.miem.gub.uy/
12. World Bank Data (2014). Access to electricity, percentage (%) of the population. Available at https://data.worldbank.org
13. Latin American Energy Organization (OLADE) (2013). The small hydro plants in Latin America and the Caribbean. Available at http://www.olade.org/sites/default/files/presentaciones-sej/2013/13Brasil-SmallHydro-SmallHydroinLAC.pdf
14. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
15. World Economic Forum (WEF) (2017). The Global Competitiveness Report 2016-2017. El indicador calidad del suministro eléctrico" rankea a los paises a partir de la siguiente pregunta: "In your country, how reliable is the electricity supply (lack of interruptions and lack of voltage fluctuations)? [1 = extremely unreliable; 7 = extremely reliable]. Available from http://www3.weforum.org/docs/GCR2016-2017/05FullReport/TheGlobalCompetitivenessReport2016-2017_FINAL.pdf
16. International Renewable Energy Agency (2018). Renewable Energy Capacity Statistics. Available from https://www.irena.org
17. Currie, S.(2016). Renewable energy in Latin America: Uruguay. October 2016. Norton Rose Fulbright Publication. Available fromhttp://www.nortonrosefulbright.com/knowledge/publications/134778/renewable-energy-in-latin-america-uruguay
18. Government of Uruguay (2017). Investment Opportunities: Renewable Energies. September 2017. Available from https://www.uruguayxxi.gub.uy/uploads/informacion/Renewable%20Energies%20Report%20-%20September%202017-8.pdf

2.3.13 Venezuela

International Center on Small Hydro Power (ICSHP); Morella C. Gilarias, Ministry of Popular Power for Electric Energy; Carlos F. M. Ramirez, Electrical National Corporation

Key facts

Population	31,977,060[1]
Area	912,050 km[2] [2]
Climate	Venezuela has a mild tropical climate, with a rainy period between May and November, which is mainly referred to as winter by the locals. Average high temperatures are between 26 °C and 28 °C, while lowest registered ones are in the high mountains area, the P*á*ramos, and reach below 8 °C.[3]
Topography	The country's topography is highly diverse, including plains which reach up to 500 metres above sea level and low and high mountains, some with elevations beyond 4,000 metres. Highlands and hills are covered by dense, rich forests. The highest point is in the Venezuelan Andes, Bolivar Peak, which rises to 4,978 metres.[4]
Rain pattern	According to data collected from 1901 to 2015, annual precipitation is approximately 1,643 mm on average. The lowest monthly precipitation registered was 9 mm, while the highest reached 433 mm.[5]
Hydrology	There are over 1,000 rivers in Venezuela, the country having rich water resources. The Orinoco River is the eight largest in the world and one of the most important rivers in Venezuela. It is navigable and has numerous tributaries. One of the most known tributaries is Rio Apure. Another major river of the country is Caroni, which also has very high hydropower potential and has significantly contributed to the electricity production in Venezuela.[6]

Electricity sector overview

At the end of 2017, the total installed capacity in Venezuela was approximately 36,561 MW. Roughly 53 per cent were from thermal power plants, while hydropower accounted for slightly over 46 per cent of the energy mix. The installed capacity of wind power plants was 96 MW.[7] Figure 1 offers more information on installed electricity capacity by source.

Figure 1.
Installed electricity capacity by source in Venezuela (MW)

Source: Guarenas[7]

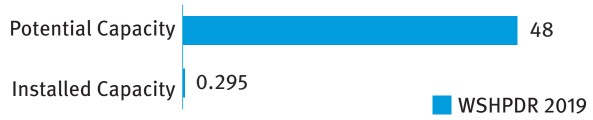
At the end of 2016, total electricity production was 115,600 GWh. More recent data on generation is currently unavailable. In comparison to 2015, electricity generation decreased by roughly 9 per cent in 2016.[8] Access to electricity was almost 100 per cent in the very same year. Approximately 96 per cent of the rural population had access to electricity, while urban access to electricity reached 100 per cent. Only 11 per cent of the total Venezuelan population lives in the rural regions, therefore total access to electricity as percentage of population was estimated at 99.6 per cent.[9] However, the electricity system in the country lackas reliability with blackouts occuring on a daily basis. Venezuela is undergoing an electricity crisis, as the situation has not improved in many years, frequent interruptions in the energy provision occuring throughout the country. The monthly electricity reports of the state-owned National Electricity Company/*Corporacion Electrica Nacional* (Corpoelec) were discontinued in 2009. In addition, the annual management report of the Ministry of Energy has not been disclosed since 2014. Moreover, the accountability document presented to the National Assembly did not include electricity generation figures. It has therefore been extremely challenging to obtain information on the electricity sector from reliable sources.[10]

In 2017, new electricity tariffs were made official in Venezuela. For residential consumers, the first 200 kWh were estimated at a price of approximately 101.5 Venezuelan Bolivars (equivalent of US$ 10.1). The price for the consumption higher than 200 kWh is 3.2 Venezuelan Bolivars per kWh (0.32 US$/kWh). For commercial consumers, the price per kWh is 0.76 Venezuelan Bolivars or roughly 0.076 US$/kWh.[11]

Small hydropower sector overview

The development of small hydropower (SHP) plants in Venezuela has played an important role in lowering the costs of electricity and improving the accessibility to sources of energy. There is no specific definition for SHP in the country. Therefore, in order to facilitate data comparison, the report refers to SHP as plants of up to 10 MW. There are several SHP plants in Venezuela, all of them below 1 MW. The total installed capacity is at least 295 kW.[12] Small hydropower potential in the country is quite high, estimated at 48 MW, and thus below 1 per cent of the potential has been developed so far.[13]

Figure 2.
Small hydropower capacities in Venezuela (MW)



Source: Marrufo,[12] GOEA[13]

Note: Venezuela is a new country introduced in the *WSHPDR 2019*

The oldest SHP plant in Venezuela is the micro-station Kavanayen, which was completed in 1957. It is located near River Apacairao and has a Francis turbine manufactured in Swizerland. The installed capacity of the plant is 110 kW and could serve an area with 376 inhabitants. The SHP plant Kamarata commenced operation in 1962. This plant has a Francis turbine fabricated in Spain and an installed capacity of 125 kW. The electricity generated could provide for an area with 571 inhabitants. The SHP plant Woken was installed in 1983, in the superior basin of Caroni River. The installed capacity of the plant is 60 kW and a population of roughly 350 could benefit from its electricity production. There are also the SHP plants of San Ignacio and San Francisco de Yuruani. Their installed capacity is unknown. The plants are located near river Yuruani and could serve 500 people.[12] Table 1 offers more information on potential sites discovered for SHP plants development.

Table 1.
Potential small hydropower sites in Venezuela and their estimated capacity (MW)

Region	*River*	*Potential (MW)*
Perija	El Palmar	3.20 MW
Perija	Apon	3.10 MW
Nor Occidental Andina	La Grita	8.20 MW
Nor Occidental Andina	Motatan	3.52 MW
Nor Occidental Andina	Torondoy	3.40 MW
Sur Occidental Andina	Acequia	8.39 MW
Sur Occidental Andina	Guache	4.30 MW
Sur Occidental Andina	Masparro	2.29 MW
Amazonas	Cataniapo	10.00 MW
Amazonas	Villacoa	1.89 MW
Total		**48.29 MW**

Source: GOEA[13]

There are no known feed-in tariffs or other incentives for SHP. As the country is in a lengthy electricity-sector crisis, SHP could be one of the solutions to ensure a more efficient access to electricity.

Renewable energy policy

There are multiple plans and initiatives to further disseminate renewable energy projects in Venezuela. The Development Plan for Renewable Energy Sources (PDFRE) considers renewable sources of energy such as solar (photovoltaic and thermal), wind, biomass, mini/micro-hydropower and geothermal plants. PDFRE was part of the Plan for Economic and Social Development of the Nation 2007-2013. The Pilot Plan for Wind Power Generation (PPGE) aims at installing 100.32 MW of wind power plants in Los Taques. In addition, a total of 144 MW from wind power plants are planned to be developed in different locations in Venezuela such as the State of Falcon, Sucre State and Isla de Margarita.[14] The dissemination of diverse renewable energy sources in the country has been considered slow and thus Venezuela is mostly relying on fossil fuels production and large hydropower.

The Homeland Programme 2013-2019 is the most recent proposed by the Government of Venezuela. The plan includes both a short-term (2013-2019) and a long-term (2014-2033) objective. By 2019, the programme aims to develop an additional 613 MW from renewable energy sources. Approximately 500 MW will be from wind power sources.[15] In 2018, no further updates were made official, with regards to the Homeland Programme.

Barriers to small hydropower development

The barriers to SHP development might also apply to the dissemination of other renewable energy resources. There are multiple challenges to be tackled, in order to achieve more sustainable development. The current electricity sector crisis represents a constant reminder that SHP as well as other renewable energy sources may, in time, tackle the existent issues of the sector. Most noteworthy barriers to SHP are the following:

- Large hydropower is considered much more profitable than SHP and therefore there is limited interest in further implementing or investing in SHP projects;
- Due to multiple complaints and protests resulting from the lengthy electricity crisis, the Government of Venezuela mostly considers projects that could offer higher electricity coverage for the population;
- Lack of local expertise in the SHP sector, as well as limited information on the actual SHP potential of the country;
- Limited information on the existent plants, their generation potential and whether an upgrading or refurbishment project is necessary.

References

1. World Bank (WB) (2017). Population, total: Venezuela. World Population Prospects: 2017 Revision. Available from https://data.worldbank.org/indicator/SP.POP.TOTL
2. World Bank (WB) (2017). Surface area: Venezuela. Available from https://data.worldbank.org/indicator/AG.SRF.TOTL.K2

3. United States Library of Congress (n.d.). Country Studies: Venezuela, Climate. Available from http://countrystudies.us/venezuela/9.htm
4. Heckel, H.D. et al (2018). Venezuela. Encyclopaedia Britannica. 19 August 2018. Available from https://www.britannica.com/place/Venezuela
5. Trading Economics (2018). Venezuela Average Precipitation: 1901 – 2015 data. Available from https://tradingeconomics.com/venezuela/precipitation
6. United States Library of Congress (n.d.). Country Studies: Venezuela, Rivers. Available from http://countrystudies.us/venezuela/10.htm
7. Guarenas, L.M. (2018). Situacion actual y futura de la electricidad en Venezuela/ Current and future situation of electricity in Venezuela. Global realities of energy and petrol conference. Presentation. Available from https://www.slideshare.net/plumacandente/situacion-actual-y-futura-de-la-electricidad-en-venezuela-2018
8. British Petroleum (BP) (2017). BP Statistical Review of World Energy June 2017. Available from https://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review-2017/bp-statistical-review-of-world-energy-2017-full-report.pdf
9. World Bank (2016). Access to electricity data. Sustainable Energy for All database. Available from https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=CM
10. Pardo, D. (2015). Por que se va tanto la luz en Venezuela. BBC news. Available from https://www.bbc.com/mundo/noticias/2015/10/151028_venezuela_luz_electricidad_crisis_dp
11. Ballesteros, A. (2017). Estas son las tarifas electricas en Venezuela : Corpolec. 3rd of March 2017. Available from http://elestimulo.com/elinteres/estas-son-las-tarifas-electricas-vigentes-desde-diciembre-en-venezuela/
12. Marrufo, J.C. (n.d.). Microcentrales Hidroelectricas en Venezuela. Available from https://www.monografias.com/trabajos13/micro/micro.shtml
13. Grupo Orinoco Energya y Ambiente (GOEA) (2015). Energy Security: Threats to hydroelectric generation in Venezuela: National Hydropower Potential statistics. Authored by Engineer Jesus Augusto Gomez. 28 May 2015. Available from https://grupoorinoco.files.wordpress.com/2015/07/potencial-hidroelc3a9ctrico-nacional-j-gc3b3mez.pdf
14. Renewable Energy and Energy Efficiency Programme Policy Database (REEP) (2012). Venezuela. Reegle. Available from http://www.reegle.info/policy-and-regulatory-overviews/VE
15. International Renewable Energy Agency (IRENA) (2015). Renewable Energy Policy Brief: Venezuela. Available from http://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_RE_Latin_America_Policies/IRENA_RE_Latin_America_Policies_2015_CountryVenezuelaashx?la=en&hash=20A98408B28B93B690D038D850FC6B0E665AB388

2.4 Northern America

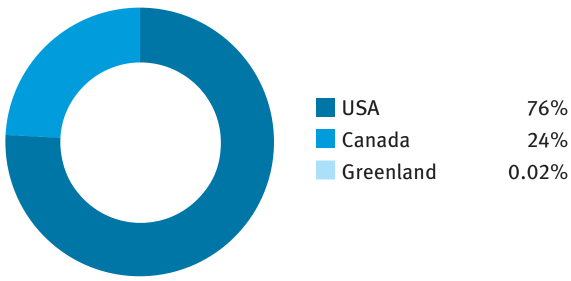
Bryan Karney and Richard Hendriks, University of Toronto

Introduction to the region

According to the United Nations classification, Northern America includes Bermuda, Canada, Greenland, Saint Pierre and Miquelon and the United States of America (USA). The current report covers Canada, Greenland and the USA, with the primary focus being Canada and the USA, due to their physical size, population and installed small hydropower.

The three countries are diverse in geography, politics, demographics, economics, ecology and climate. Despite being the world's largest island, Greenland has a sparse population with only a small fraction of its land surface not covered with ice. Canada is a large country, with an east-west extent spanning over 5,500 km and a north-south extent of more than 4,600 km. The country includes multiple climate regions, varying topographies, diverse populations and extensive thinly populated regions. Some areas of Canada and the USA have a high density of lakes while others are almost barren of surface water. Similarly, the USA comprises extremely diverse geographic and climatic conditions ranging from arctic in Alaska, tropical in Hawaii, Mediterranean in California, arid in the South-west and temperate across much of the country. An overview of the countries of Northern America is presented in Table 1.

Figure 1.
Share of regional installed capacity of small hydropower up to 10 MW by country in Northern America (%)



Source: *WSHPDR 2019* [3]

Table 1.
Overview of countries in Northern America

Country	Total population (million)	Rural population (%)	Electricity access (%)	Electrical capacity (MW)	Electricity generation (GWh/year)	Hydropower capacity (MW)	Hydropower generation (GWh/year)
Canada	37.1	19	100	143,000	650,245	80,800.0*	392,647*
Greenland	0.06	13	100	140	549	9	371
USA	328.9	18	100	1,084,783	4,000,000	101,200*	294,000*
Total	**366.1**	-	-	**1,227,923**	**4,650,794**	**182,009**	**687,018**

Source: *WSHPDR 2016*,[2] *WSHPDR 2019*,[3] WB,[4] Statistics Canada[5]

Note:* Including pumped storage hydropower.

The greatest share of the known small hydropower (SHP), having installed capacity up to 10 MW, is located in the USA (Figure 1). Estimated at 4,734 MW, the SHP installed capacity of Northern America has decreased by 0.9 per cent compared to the *World Small Hydropower Development Report (WSHPDR) 2016*. This is due to a decrease in the capacity in the USA, while the installed capacities of Canada and Greenland remained unchanged (Figure 3).

Small hydropower definition

The definition of small hydropower (SHP) in Canada is perhaps influenced by its history of very large-scale hydropower projects, and thus is characteristically defined to include systems of up to 50 MW of generating capacity. In the USA, there is no widely accepted definition, but 10 MW is often accepted since this is the largest project that can qualify for an SHP exemption with the Federal Energy Regulatory Commission. In Greenland, the threshold is also 10 MW, in accordance with the Danish standard as an overseas constituent country of Denmark (Table 2).

Regional small hydropower overview and renewable energy policy

The installed capacity of SHP up to 10 MW in Northern America is 4,734 MW (Table 2), which accounts for 2.6 per cent of the region's total installed hydropower capacity and 39.9 per cent of the known SHP potential up to 10 MW. However, when taking into account the definition of SHP up to 50 MW used in Canada, the potential of SHP in the region rises to almost 26,000 MW, of which approximately 27 per cent has been developed to date (Figure 2).

Table 2.
Small hydropower capacities in Northern America (local and ICSHP definition) (MW)

Country	Local SHP definition	Installed capacity (local def.)	Potential capacity (local def.)	Installed (<10 MW)	Potential (<10 MW)
Canada	up to 50	3,400.0	15,000.0	1,113.0	1,113.0*
Greenland	up to 10	8.8	183.1	8.8	183.1
USA	-	-	-	3,612.0	10,583.0
Total		-	-	**4,734**	**11,879**

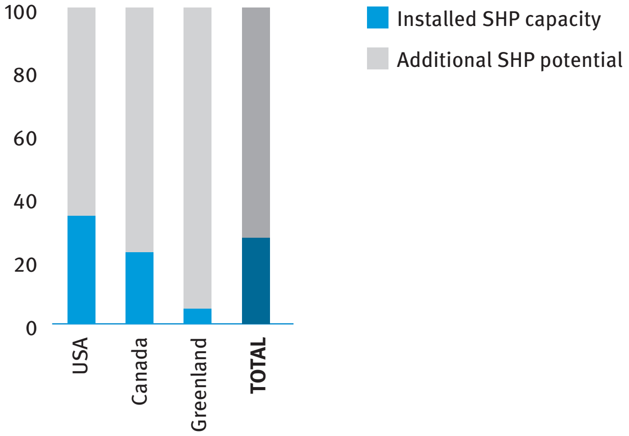
Source: *WSHPDR 2016*,[2] *WSHPDR 2019*[3]

Note:* The estimate is based on the installed capacity as no data on potential capacity is available.

Extensive transportation, infrastructure and electrical networks span the continental USA and the southern regions of Canada. Of significance, electricity production across Northern America varies considerably in terms of generation mix, including regional systems dominated by coal, natural gas, hydroelectric and nuclear power. The contribution of renewable energy sources, including both conventional and small hydropower, is highly regionally specific.

An overview of SHP in the countries of Northern America is outlined below. The information used in this section is extracted from the country profiles, which provide detailed information on SHP capacity and potential, among other energy-related information.

Figure 2.
Utilized small hydropower potential by country in Northern America (local SHP definition) (%)



Source: *WSHPDR 2019*[3]

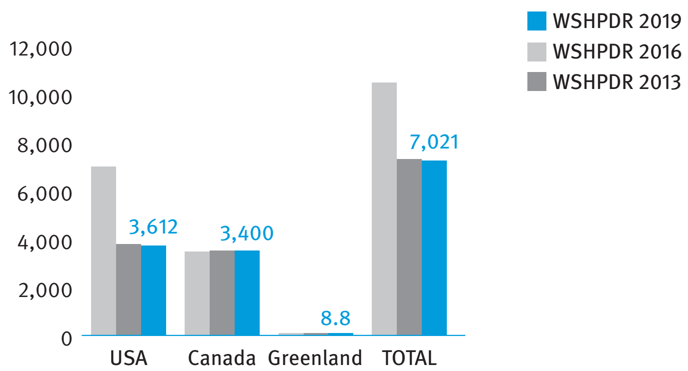
Note: This Figure illustrates data for local SHP definitions or the definition up to 10 MW in case of the absence of an official local one.

The installed capacity of SHP up to 50 MW in **Canada** is 3,400 MW, while the technical potential is estimated to be 15,000 MW, indicating that 23 per cent has been developed to date. Since the *WSHPDR 2016*, the installed and potential capacities for SHP up to 50 MW have remained unchanged. No new data has been made available for SHP up to 10 MW either. Therefore, it is assumed to have remained at the same level (1,113 MW).[2] SHP accounts for approximately 4 per cent of total hydropower installed capacity in Canada. In general, hydropower plays an important role in the country's energy mix, accounting for approximately 60 per cent of its electrical energy. Some Canadian provinces, such as British Columbia, Manitoba and Quebec, are nearly exclusively hydroelectric, while other regions contain virtually no small or large hydropower.

Greenland has two SHP plants with a combined capacity of 8.8 MW, while the potential is estimated at over 180 MW. Thus, only 4.8 per cent of the known potential has been developed. The small degree of utilization might be to some extent explained by low levels of electricity consumption. Since the *WSHPDR 2016*, no updates have been made available with regards to the country's SHP capacities, and no further plans to develop SHP have been announced. While hydropower remains by far the most important renewable energy source in Greenland, there have been several small-scale initiatives to examine the potential of other renewable energy technologies, including solar and wind.

The **USA** has the greatest capacity of SHP up to 10 MW in the region at 3,612 MW, which accounts for 34 per cent of the country's known technical SHP potential. This cumulative installed capacity comes from 1,646 SHP plants. Even though hydropower accounts for only 7 per cent of the country's electricity generation, similar to Canada there are regions in the USA that are dominated by hydroelectric generation (e.g. north-west and Appalachia). As of the end of 2017, the "pipeline" of planned SHP projects contained 165 projects with a total combined capacity of 420 MW, the majority of which (159 projects) involve adding hydropower generation to existing dams or conduits.

Figure 3.
Change in installed capacity of small hydropower from *WSHPDR 2013* to *2019* by country in Northern America (MW)



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

Note: *WSHPDR* stands for *World Small Hydropower Development Report*. For Canada, data is for SHP up to 50 MW; other countries up to 10 MW.

Among the countries of the region, **feed-in tariffs (FITs)** have been introduced in Canada and the USA. In Canada, incentives for renewable energy sources are provided on the provincial level, leading to a large variation in such incentives across the country. Ontario recently suspended its FIT programme in 2016 and the Nova Scotia Community FIT Programme is no longer accepting applications. In the USA, individual states have adopted policies to encourage renewable energy development, including renewable portfolio standards and FITs. Some states have created programmes and policies specifically to financially support the development of SHP. Certain incentives are also provided on the federal level.

Barriers to small hydropower development

Issues including community remoteness, the availability of viable alternative sources and proximity to transmission grids all play important roles in encouraging or discouraging the development of hydropower resources. One of the distinct challenges of hydropower development is that it is almost never commoditized – invariably every project requires custom development and grounding in general principles as well as local conditions and constraints. Furthermore, development challenges are often as severe for small projects as for large, implying that fixed costs are proportionally larger for smaller projects. Site development often depends not only on whether the opportunity is greenfield or brownfield, but also on a variety of other site, geological, hydrological, socioeconomic and technical considerations.

The development of SHP in **Canada** is challenged by the low and declining cost of new wind energy resources as well as the fragmented approach to provincial electricity policies and renewable energy targets. In addition, hydropower development in Canada has to take into consideration Aboriginal and treaty rights. In the northern parts of the country, SHP development can be complicated by ice formation, methylmercury accumulation and potential impacts on local and regional biodiversity.

In **Greenland**, the barriers to SHP development are particularly experienced in the more scarcely populated areas. Due to towns and settlements being scattered along the coast often with great distances between them as well as the challenging terrain, the transportation of electricity across the country is often associated with great costs and losses.

Some of the challenges that the developers of SHP may face in the **USA** include the uncertain federal regulatory processes that have made it difficult for investors to obtain long-term, low-cost financing, as well as regulatory issues associated with water quality certifications and other state and local environmental requirements. Furthermore, SHP has to compete with other electricity generating technologies, including natural gas, wind and solar power. While a certain share of the untapped SHP potential is associated with the addition of SHP facilities to existing dams and conduits, there has been no comprehensive national assessment regarding conduit opportunities. Moreover, the owners of existing dams and conduits tend to be cautious and risk-averse. Additionally, there is a lack of standardized technology, and the requirements of grid interconnection can be challenging for SHP projects.

References

1. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
2. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
3. LIU, D., LIU, H., WANG, X., and Kremere, E., eds. (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
4. World Bank (2017). Rural population (% of total population). Available from https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS
5. Statistics Canada (2019). Electric power annual generation by class of producer. Available from https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2510002001&pickMembers%5B0%5D=1.1&pickMembers%5B1%5D=3.1

2.4.1 Canada

Bryan Karney, Richard Hendriks, Sharon Mandair and Samiha Tahseen, University of Toronto

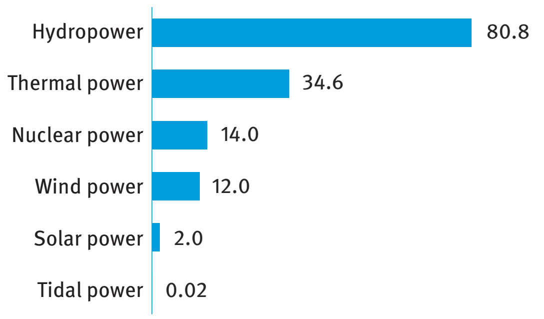
Key facts

Population	37,058,856[1]
Area	9,985,000 km[2]
Climate	The climate varies greatly throughout the country, with interior regions such as the prairies (e.g. Manitoba, Alberta) experiencing more extreme temperatures. More temperate weather is common along the west coast within the province of British Columbia. Average summer temperatures from July to August range between 15 °C and 27 °C, while average winter temperatures from January to February range between –30 °C and 0 °C.[2]
Topography	The western part of the country has a mountain range that stretches through British Columbia and Alberta and down into the United States. In the northern part of this mountain range is Mount Logan, the highest point, at 5,959 metres above sea level.[3] The interior provinces are dominated by the Great Plains and the Canadian Shield, which are relatively flat. Towards the Atlantic coast is the geologically older Appalachian mountain range.[4]
Rain pattern	In the western and eastern coastal regions, rainfall is 1,100 mm to 1,500 mm per year. In the interior regions, it is 400 mm to 800 mm and in the northern regions it is 250 mm to 300 mm. Snowfall in the east coast can reach 300 cm and in the west coast 50 cm.[5]
Hydrology	Nine per cent of the total area of Canada is made up of 8,500 rivers and 2 million lakes.[6] There are 12 rivers over 1,000 km long, the longest being the Mackenzie River (4,250 km), which drains into the Arctic Ocean.[7] By discharge, the St Lawrence River is the largest river, with an average flow of 9,850 m³/s.[8]

Electricity sector overview

The electricity sector in Canada has an installed capacity of 143 GW (Figure 1), generating some 650 TWh in 2017, with net exports to the United States of 62.8 TWh.[9,10] The major sources of electricity generation are hydropower (60 per cent), fossil fuels (18 per cent) and nuclear power (15 per cent). The remainder comes from a combination of wind power, biomass, solar power and tidal power.[10]

Figure 1.
Installed electricity capacity by source in Canada (GW)



Source: Statistics Canada[9]

The electricity mix varies substantially, with British Columbia, Manitoba, Québec, and Newfoundland and Labrador generating electricity predominantly from hydropower sources. Alberta, Saskatchewan, Nova Scotia and New Brunswick depend substantially on fossil fuel generation. Ontario depends largely on nuclear energy and hydropower. Among other renewable energy sources, wind power has shown rapid growth over the past two decades and in 2016 accounted for 8 per cent of total national installed capacity.[11] Table 1 shows the existing generating capacity within the major Canadian provinces.

Canada has a predominately north-south transmission network, with several interconnections to the United States.[12] The transmission grid, apart from facilitating interprovincial trade, plays a key role in exporting electricity to the US markets. Overall, Canada exports on the order of 7 to 9 per cent of its annual electricity generation and has traditionally been a net electricity exporter.[13]

In Canada, regulatory and policy control over the electricity industry is primarily vested provincially. In most instances, provincial governments have ownership over generation assets, especially hydropower, nuclear power and conventional steam plants. Generation and transmission are often provided through a public entity (e.g., British Columbia, Québec, Manitoba) or produced in a competitive market (e.g., Alberta, Ontario).[13] The private sector nevertheless, in all provinces, owns an important share of the generation capacity.

Table 1.
Installed generation capacity by province in 2016 (MW)

	N.L.	*P.E.I.*	*N.S.*	*N.B.*	*Que.*	*Ont.*	*Man.*	*Sask.*	*Alta.*	*B.C.*
Hydropower	6,761	-	370	968	40,543	9,106	5,402	867	1,219	15,459
Wind power	54	204	596	294	3,408	4,969	242	198	1,497	502
Tidal power	-	-	20	-	-	-	-	-	-	-
Solar power	-	-	-	-	-	2,025	-	-	2	-
Thermal power	587	106	1,973	2,535	1,454	10,425	559	3,297	11,846	1,513
Nuclear power	-	-	-	705	-	13,328	-	-	-	-
Total	**7,402**	**310**	**2,959**	**4,502**	**45,405**	**39,854**	**6,203**	**4,362**	**14,562**	**17,474**

Source: Statistics Canada[9]

The national transmission grid is a collection of provincial grids that are linked together through varying levels of intertie capacity. British Columbia, Manitoba, Ontario and Québec have the largest transmission interconnections to the regional US markets. The system operator coordinates power flows in real time, with Ontario, Alberta and New Brunswick having Independent System Operators. In most other provinces, the provincial utility operator also owns the transmission assets.[14]

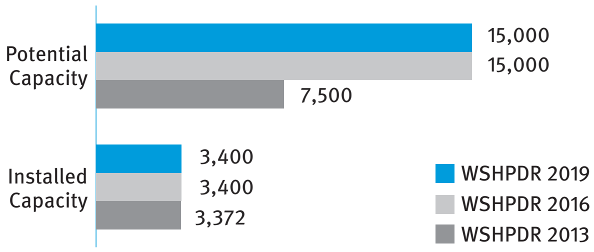
At the federal level, actions directed at contributing to meeting or exceeding the country's 2030 climate change target of a 30% per cent reduction below 2005 greenhouse gas emissions levels include pricing carbon pollution, clean technology and complementary actions to reduce emissions.[15] Ontario has entirely eliminated coal generation, and other provinces (Alberta, Saskatchewan, New Brunswick and Nova Scotia) face pending federal coal regulations.[16] Most provinces pursue demand-side management programmes and support smart grid investments, including the installation of smart meters (e.g., British Columbia and Ontario).

Canadians enjoy some of the lowest residential electricity prices among the Organization for Economic Cooperation and Development (OECD) countries.[17] Each province has its own electricity policy and regulatory agency, leading to somewhat disparate electricity tariffs. Québec, British Columbia, Manitoba, and Newfoundland and Labrador produce their electricity almost exclusively from hydropower facilities.[9,11] Given the low operational cost of their generation portfolios, these provinces have the lowest electricity rates in Canada. The lack of additional low-cost hydropower potential in Alberta, Saskatchewan, Ontario, New Brunswick and Nova Scotia led to a reliance on thermal generation (fossil fuel and nuclear), resulting in higher production costs. Provinces have separate regulatory entities for reviewing and approving utility resource plans, revenue requirements and rates. In a majority of the provinces, utilities are operating as regulated monopolies with the exception of Ontario and Alberta, which have at least partially deregulated their electric industry. A few key responsibilities are still handled by the Federal Government, including issuing permits for inter-provincial and international transmission lines, and environmental assessment of major hydroelectric and transmission developments.[18] The Federal Government retains some jurisdiction and permit responsibilities on issues relating to fisheries, migratory birds and species at risk.[19]

Small hydropower sector overview

Natural Resources Canada defines small hydropower (SHP) as less than 50 MW of generating capacity.[20] However, in the absence of an international convention, a 10 MW limit can also be used. The installed capacity of SHP in Canada is 3,400 MW (up to 50 MW), while the technical potential is estimated to be 15,000 MW, indicating that 23 per cent has been developed to date. Since the *World Small Hydropower Development Report* (*WSHPDR*) *2016*, the installed capacity for SHP up to 50 MW has remained unchanged (Figure 2).

Figure 2.
Small hydropower capacities 2013/2016/2019 in Canada (MW)



Source: Natural Resources Canada,[20] *WSHPDR 2016*,[21] *WSHPDR 2013*[22]

Note: Data for SHP up to 50 MW.

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

The 3,400 MW of SHP capacity (up to 50 MW) accounts for 4.2 per cent of total installed hydropower capacity in Canada. As each province has a unique strategy, the plans for future development of small hydropower tend to vary across jurisdictions. With the recent suspension of BC Hydro's Standing Offer Programme, which targeted small producers of electricity (less than 15 MW), no province currently has specific published plans to develop small hydropower, with the focus in most provinces shifting to refurbishing existing aging infrastructure.[23] Alberta has initiated a renewable electricity programme to achieve 30 per cent renewable electricity by 2030, and though no hydroelectric projects are included in the nearly 1,400 MW of renewable generation procured to date, several hydroelectric and pumped storage facilities are in the planning stages.[24]

Renewable energy policy

Due to the provincial dominance over the electricity sector, there is a large variation in incentives provided for clean, renewable development across Canada. The schemes are also subject to frequent amendments and adjustments. Current and recent renewable policy measures include the following:

- Research and Development
  The current investment programmes of Natural Resources Canada include the Energy Innovation Programme supporting clean technology research and development, and the Emerging Renewable Power Programme supporting renewable energy projects facing higher risks, costs and uncertainties.[25]
- Standing Offer Programmes
  BC Hydro recently suspended indefinitely its standing offer programmes for the procurement of renewable energy resources. These programmes typically offered 20-year power purchase agreements to encourage the development of small (100 kW to 15 MW) clean or renewable electricity projects throughout British Columbia.[23]
- Feed-in tariff Programmes
  These programmes assure priority grid connection and provide long-term power purchase agreements (40 years for hydropower and 20 years for others) for electricity generated from renewable energy resources, subject to capacity restrictions. Ontario suspended its feed-in tariff programmes in 2016, and the Nova Scotia Community Feed-in tariff Programme is no longer accepting applications.[26, 27]
- Net Metering
  Net metering allows generators to send the excess electricity, after their own use, to the grid. The credit received in return can be applied against future electricity use or at times, can be subjected to annual monetary returns. Net metering programmes are available in almost every province across Canada.
- Direct Procurement
  Provincial utilities or system operators typically procure renewable energy through a competitive request for proposal (RFP) process pursuant to specific targets or policies established by provincial governments. Several provinces recently completed renewable procurement processes, with the only active procurement process occurring in Alberta.[24]

Barriers to small hydropower development

Overall, the situation in Canada, as in most jurisdictions, is dynamic and difficult to forecast in detail. Some anticipate that a hydropower renaissance is possible with hydropower resources playing a larger role in the quest for a more renewable, sustainable, stable and economical power system. The current focus in the Canadian industry is on renewal and redevelopment of existing resources to improve performance efficiency and increase available capacity, and development of pumped storage for integration of intermittent renewable energy sources. Some challenges and opportunities include:

- The low and declining cost of new wind energy resources presents the largest challenge to the development of new small hydropower sites, particularly those that cannot provide energy storage.
- The fragmented approach to provincial electricity policies and renewable energy targets contributes to the underdevelopment of renewable energy resources, including hydropower. Transboundary cooperation between upstream and downstream jurisdictions can be challenging.
- Another common consideration for hydropower development throughout Canada is Aboriginal and treaty rights. Indigenous communities are diverse, and often their economic and cultural livelihood depends on water courses. Consultation with Indigenous communities is now an established requirement of Canadian law, while accommodations often include environmental mitigations and direct project participation in the form of equity partnerships.
- From a more technical perspective, development of hydroelectric projects in northern environments presents particular challenges in relation to ice formation, methylmercury accumulation and impacts on local and regional biodiversity.

References

1. Statistics Canada (2018). *Canada's population estimates, second quarter 2018.* Available from https://www150.statcan.gc.ca/n1/daily-quotidien/180927/dq180927j-eng.htm?HPA=1&indid=4098-1&indgeo=0
2. Statistics Canada (2007). *Weather conditions in capital and major cities (Temperature).* Available from http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/phys08b-eng.htm
3. Earle, T. (2011). *Mount Logan.* Available from http://www.canadiangeographic.ca/magazine/ja11/mount_logan.asp
4. National Geographic (2015). *North America: Physical Geography.* Available from http://education.nationalgeographic.com/encyclopedia/north-america-physical-geography/
5. Statistics Canada (2007). *Weather conditions in capital and major cities (Precipitation).* Available from www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/phys08a-eng.htm
6. Canadian Council of Ministers of Environment (2014). *Lakes and Rivers.* Available from www.biodivcanada.ca/default.asp?lang=En&n=8BBDAD3A-1
7. Environment Canada (2013). *Rivers.* Available from https://www.ec.gc.ca/eau-water/default.asp?lang=En&n=45BBB7B8-1
8. Natural Resources Canada (2004). *Rivers.* Available from http://web.unbc.ca/~sdery/datafiles/rivers.html
9. Statistics Canada (2018). *Installed plants, annual generating capacity by type of electricity generation.* Available from https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2510002201
10. Canada, National Energy Board (2019). *Provincial and Territorial Energy Profiles.* Available from https://www.neb-one.gc.ca/nrg/ntgrtd/mrkt/nrgsstmprfls/cda-eng.html
11. Canadian Electricity Association (CEA) (2018). *Canada's Electricity Industry.* Available from www.electricity.ca/media/Electricity101/Electricity101.pdf
12. Canada, National Energy Board (2019). *Electricity Trade Sum-*

mary. Available from https://www.neb-one.gc.ca/nrg/sttstc/lctrct/stt/lctrctysmmr/lctrctysmmr-eng.html

13. Canada, Environment and Climate Change Canada (2008). *Economic Scan of Canada's Energy Sector.* Ottawa: Government of Canada. Available from www.ec.gc.ca/Publications/default.asp?lang=En&xml=73EC7D79-5F34-4C4C-ADBE-66CAAFF-5DAC2.
14. The Conference Board of Canada (2011). *Canada's Electricity Infrastructure: Building a Case for Investment.* Available from www.electricity.ca/media/ReportsPublications/11-257_ElectricityInfrastructure%5B1%5D.pdf
15. Canada, National Energy Board (2018). *Canada's Energy Future 2018 – Energy Supply and Demand Projections to 2040 – An Energy Market Assessment.* Available from https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2018/2018nrgftr-eng.pdf.
16. Government of Canada (2018). *Proposed amendments to coal-fired electricity regulations and proposed natural-gas-fired electricity regulations*. Available from https://www.canada.ca/en/environment-climate-change/news/2018/02/proposed_amendmentstocoal-firedelectricityregulationsandproposed.html
17. Organization for Economic Cooperation and Development (OECD) (2004). *OECD Economic Survey of Canada 2004: Electricity Sector.* Available from www.oecd.org/dataoecd/52/0/33847613.pdf
18. Canada, National Energy Board (2015). *Who We Are.* Available from www.neb.gc.ca/bts/whwr/index-eng.html
19. *Canadian Environmental Assessment Act*, 2012 (S.C. 2012, c. 19, s. 52) Available from https://laws-lois.justice.gc.ca/eng/acts/c-15.21/
20. Natural Resources Canada (2018). *Small Hydropower.* Available from www.nrcan.gc.ca/energy/renewable-electricity/small-hydropower/7363
21. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
22. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
23. BC Hydro (2019). *Standing Offer Program*. Available at: https://www.bchydro.com/work-with-us/selling-clean-energy/standing-offer-program.html
24. Alberta Electric System Operator. (2019). *Renewable Electricity Program*. https://www.aeso.ca/market/renewable-electricity-program/
25. Natural Resources Canada (2019). *Funding, Grants and Incentives.* Available from https://www.nrcan.gc.ca/energy/funding/4943
26. Government of Nova Scotia (2019). *COMFIT*. Available from https://energy.novascotia.ca/renewables/programs-and-projects/comfit
27. Independent Electricity System Operator (IESO) (n.d.). *FIT Archive.* Available from http://www.ieso.ca/en/Sector-Participants/Feed-in-Tariff-Program/FIT-Archive

2.4.2

Greenland

Mikael Togeby, Ea Energy Analyses A/S

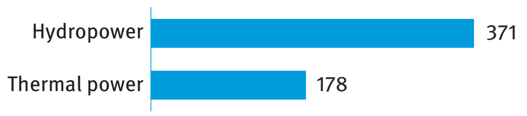
Key facts

Population	56,170[1]
Area	2,166,086 km[2]
Climate	The climate is arctic to sub-arctic with cool winters and cold summers.[1] Monthly average temperatures in the capital, Nuuk, vary between –8 °C and 7 °C. In Upernavik in the north the variation is between –20 °C and 6 °C.[24]
Topography	Flat to gradually sloping icecap covers all but a narrow, mountainous, barren, rocky coast.[1] The ice cap is up to 3,200 metres thick.[24]
Rain pattern	The average annual precipitation is 756 mm. On average, there are 94 days per year with more than 0.1 mm precipitation. Most of the annual precipitation falls in September, with an average of 89 mm. The driest weather is in March, with an average of 39 mm.[2,24]
Hydrology	The Greenland ice cap has an estimated volume of 1.7 million km³. The Ilulissat Glacier is one of the fastest and most active glaciers in the world. It produces 10 per cent of all Greenland's ice fields, corresponding to around 35 billion tons of ice a year.[17] Across a 2,000-square-mile area of ice, over 500 active rivers and streams drain in moulins, moving the melt water into the ocean through and under the ice sheet. At the base of the ice sheet the drainage occurs at a rate between 55,000 and 61,000 cubic feet per second.[18, 24]

Electricity sector overview

In 2017, approximately 69 per cent of Greenland's electricity and heat came from hydropower. The total generation of electricity was 549 GWh in the very same year. Thermal power plants accounted for the remaining 31 per cent.[3] Nukissiorfiit, the energy company of Greenland, is the sole supplier of electricity in Greenland. Nukissiorfiit generates and transmits electricity to 17 towns and 53 settlements.[4] Nukissiorfiit is owned by the Government of Greenland, Naalakkersuisut. The electrification rate in Greenland is 100 per cent.[20]

Figure 1.
Annual electricity generation by source in Greenland (GWh)



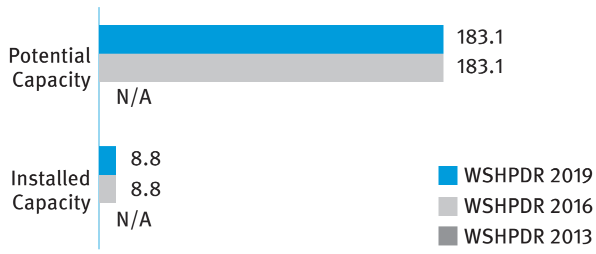
Source: Nukissiorfiit[3]

Greenland is the world's largest island and is not connected to other areas. Supply in Greenland is divided into many isolated systems. As of 1 of January 2018 a new tariff system for water and electricity was introduced. For one m³ of water consumers pay 19 Danish Crowns (DKK) (2.94 US\$/m³), while for one kWh of electricity the tariff is 1.6 DKK (0.25 US\$/kWh). Industry pays 7.85 DKK for one m³ of water (1.21 US\$/m³) and 0.66 DKK (0.10 US\$/kWh) for one kWh of electricity.[5]

Small hydropower sector overview

The definition of small hydropower (SHP) in Greenland is up to 10 MW.[4] The installed capacity of SHP remains 8.8 MW while the potential is estimated at 183.1 MW, indicating that only 4.8 per cent has been developed (Figure 2). In 2018, no updates were offered with regards to installed and potential capacity of the country. The 8.8 MW come from two small hydropower plants – Tasilaq (1.2 MW) and Qorlortorsuaq (7.6 MW). No specific plans to develop future SHP plants were made official.[8,22]

Figure 2.
Small hydropower capacities 2013/2016/2019 in Greenland (MW)



Source: Nukissiorfiit,[8,9] *WSHPDR 2013*,[23] *WSHPDR 2016*[24]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

In 1951, the Swiss geologist H. Stauber pointed out the possibility of using the great amounts of melting water from the inland ice for hydropower in Greenland. In the beginning of the 1970s, the planning of hydropower development increased in pace. Through studies of maps and climate, potential hydropower areas were identified in Western Greenland. The first hydropower plant was commissioned in 1993 in Nuuk, Buksefjorden after which a hiatus in the establishment of new hydropower plants occurred.[6, 24]

The inland ice is the world's second largest freshwater reservoir (Antarctica being the largest) and represents, with precipitation, an ideal potential for hydropower. The theoretical potential for hydropower in Greenland is large enough to supply much of Europe with electricity. However, at present, most of the localized potential remains economically sustainable.[7] Greenland is aiming to replace its diesel power plants with hydropower projects running on glacial meltwater. The latest project is the 22.5 MW station for the town of Ilussat. The unstaffed project will be built 200 m below the ground and operated remotely. This project is the third of its kind in Greenland, after the 9 MW Qorlortorsuaq project in 2007 and the 15 MW Sisimut project in 2010.[19, 24]

In 2015, Greenland had two SHP plants, Tasilaq and Qorlortorsuaq, with a total installed capacity of 8.8 MW (29 GWh/year) and three large hydropower plants with a total installed capacity of 82.5 MW (288 GWh/year). The total installed capacity is 91.3 MW of which SHP provides about 10 per cent.[8] In 2005, according to Nukissiorfiit, Greenland had a localized potential of 51 SHP facilities with a total potential of 183 MW (948 GWh/year) and 26 large hydropower facilities with a total potential of 1,724 MW (13,533 GWh/year). Thus, the total potential is 1,907 MW.[8] Note that this is the total potential and that it doesn't consider any practical or economic constraints.[3, 24]

The hydropower potential in Greenland is much greater than the installed hydropower capacity. The small degree of utilization might be explained by a lack of electricity consumption. With the launching of new mining projects and an increase in energy consumption, a greater portion of the hydropower potential might be utilized in the future. However, the pace of implementation of these new projects is uncertain. A large part of Greenland remains unexplored to date and thus the limited data might also affect the pace of future project implementation. [10, 24]

Renewable energy policy

Naalakkersuisut has consciously made an effort to educate the populace on the importance of reducing the country's CO_2 emissions. A climate campaign aimed at the population at large was aired in the spring of 2013. The campaign promoted climate friendly behaviour and encouraged citizens to reduce their consumption of fossil fuels where possible.[11] The Department of Nature, Energy and Climate, which is part of the ministries of the Greenlandic Government, provides annual support of about US$ 200,000 to development projects regarding renewable energy (RE), energy efficiency, and climate.[12] The Government of Greenland has in many years invested about 1 per cent of the country's GDP, which has led to more than 50 per cent of the energy supply coming from RE sources. [24]

Hydropower is by far the most important RE source in Greenland, but several small-scale initiatives are also worth noting. The Arctic Technology Centre (ARTEK) in Sisimuit, affiliated with the Technical University of Denmark, has launched numerous research and development projects regarding examinations of solar power potential, wind power potential, and sustainable building. The Greenlandic Government has also examined the possibilities of introducing electric cars in Nuuk. With access to surplus energy from the hydropower plant and a limited system of roads the challenges that often characterizes electric vehicle deployment are easily overcome.[13, 24]

In 2012, Naalakkersuisut requested Denmark to take territorial reservation for Greenland regarding the ratification of the second commitment period of the Kyoto Protocol. The second commitment period extends from 2013-2020. A territorial reservation means that Greenland will be exempt from international reduction commitments of greenhouse gas emissions. Throughout the first commitment period (2008-2012), however, Greenland was included in Denmark's reduction commitments. In this period Denmark committed to a 21 per cent reduction within which Greenland committed to 8 per cent.[14,24]

Barriers to small hydropower development

Barriers to SHP development are experienced especially in the more scarcely populated areas. Most relevant ones are outlined below.

- Transporting electricity across longer distances is associated with greater costs and losses, therefore many smaller towns and settlements are still dependent on an energy supply based on fossil fuels.[15] The coastline of Greenland is longer than the Earth's circumference.[1] Towns and settlements are scattered along the coast often with great distances between them.
- The challenging terrain prevents some towns and settlements from being connected by road and travel between them has to take place either by boat, plane or helicopter. In the winter, when sea ice coverage can make it difficult to move by water, most transport is by air. This is especially energy intensive.[16, 24]

References

1. The World Bank (2017). *Population, total.* World Population Prospects: 2017 Revision. Available from http://data.worldbank.org/indicator/SP.POP.TOTL.
2. The Nordic Council (2015). *Facts about Greenland.* Available from http://www.norden.org/en/fakta-om-norden-1/the-nordic-countries-the-faroe-islands-greenland-and-aaland/facts-about-greenland.
3. Greenland, Nukissiorfiit (2018). Arsregnskab 2017/ Annu-

al accounts 2017. Available from http://www.nukissiorfiit.gl/wp-content/uploads/2018/08/Nukissiorfiit_a%C-C%8Arsregnskab-dk_2017.pdf

4. Greenland, Nukissiorfiit (2014). Business relations. Available from https://www.nukissiorfiit.gl/business-relations/el/?lang=da.
5. Greenland, Nukissiorfiit (2018). *Electricity tariffs.* Available from https://www.nukissiorfiit.gl/om-os/sektorplan-for-energi-og-vandforsyning/.
6. Greenland, Nukissiorfiit (2011). Paakirtsoq og vandkraftens historie i Grønland. Available from http://www.nukissiorfiit.gl/wp-content/uploads/2012/11/Paakitsoq-og-vandkraftens-historie-i-Gr%C3%B8nland.pdf.
7. Greenland, Nukissiorfiit (2011). Buksefjorden vandkraftværk – En investering for generationer. Available from http://www.nukissiorfiit.gl/wp-content/uploads/2012/11/Vandkraftsfolder-Buksefjorden-dk-lav3.pdf.
8. Greenland, Nukissiorfiit (2005). Hydropower resources in Greenland. Survey – August 2005. Available from http://www.nukissiorfiit.gl/wp-content/uploads/2014/03/Hydropower-resources-in-Greenland.pdf.
9. Greenland, Nukissiorfiit (2015). Map of settlements. Available from https://www.nukissiorfiit.gl/kort/?lang=da.
10. Tim Boersma and Kevin Foley .(2014) The Greenland Gold Rush – Promise and Pitfalls of Greenland's Energy and Mineral Resources, Brookings, Energy Securities Initiative. Available from http://www.brookings.edu/~/media/research/files/reports/2014/09/24-greenland-energy-mineral-resources-boersma-foley/24-greenland-energy-mineral-resources-boersma-foley-pdf-2.pdf.
11. Climate Greenland (2015). Climate Campaign. Available from http://climategreenland.gl/udledning-og-reduktion/reduktionsindsatser.aspx.
12. Greenland, Naalakkersuisut (2015). Support for development projects. Available from http://naalakkersuisut.gl/da/Naalakkersuisut/Departementer/Natur-Miljoe-og-Justitsomraadet/Natur_-Energi-og-Klimaafdelingen/Energi/Tilskud-til-udviklingsprojekter.
13. Climate Greenland (2015). Renewable Energy. Available from http://www.silap-pissusaa.gl/udledning-og-reduktion/vedvarende-energi.aspx.
14. Climate Greenland (2015). International Obligations. vailable from http://www.silap-pissusaa.gl/udledning-og-reduktion/internationale-forpligtelser.aspx.
15. Climate Greenland (2015). Feasibility Studies. vailable from http://climategreenland.gl/udledning-og-reduktion/vandkraft.aspx?lang=en.
16. Climate Greenland (2015). A Greenlandic Reality. vailable from http://www.silap-pissusaa.gl/udledning-og-reduktion/en-groenlandsk-virkelighed.aspx.
17. Ice & Water Resources in Greenland (2015). Available from http://www.iceandwater.gl/.
18. Chase, Justin (2015). Rivers in Greenland – Big Contributors To The Rising Sea Level. Capital OTC, 13 January 2015. Available from:
http://www.capitalotc.com/rivers-in-greenland-big-contributors-to-the-rising-sea-level/27754/.
19. International Hydropower Association (2013). IHA HYDROPOWER REPORT. Available from: https://www.hydropower.org/sites/default/files/publications-docs/2013%20IHA%20Hydropower%20Report.pdf.
20. The World Bank (2015). Access to electricity (% of population). Available from
http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS/countries. https://twitter.com/share.
21. Canadian Electricity Association (2014). Vision 2050 – The Future of Canada's Electricity System. Available from http://powerforthefuture.ca/wp-content/uploads/2014/04/Vision2050.pdf.
22. Climate Greenland Official Website (2016). Hydropower. Available from http://climategreenland.gl/en/municipality/efforts-to-reduce/hydropower/
23. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013.* United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org.
24. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org

2.4.3

United States of America

Kurt Johnson, Telluride Energy[1]

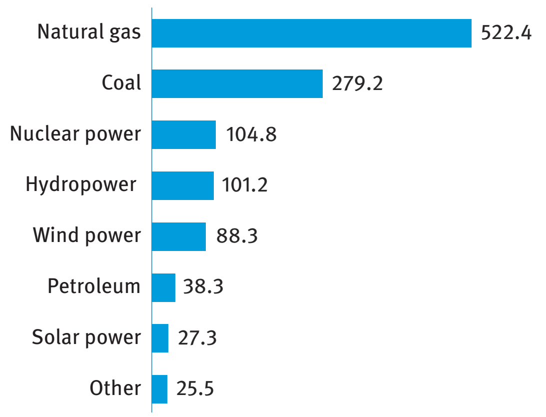
Key facts

Population	328,932,000[2]
Area	9,826,675 km^2
Climate	The climate of the USA varies widely according to location, from arctic in Alaska, tropical in Hawaii, Mediterranean in California, arid in the South-west and temperate across much of the country.
Topography	There is a large central plain with hills and low mountains in the east and mountains in the west. The highest point is Mount Denali in Alaska, at 6,194 metres above sea level. The lowest point is Death Valley, California, at 86 metres below sea level.
Rain pattern	Rainfall varies according to location. State-wide averages of annual rainfall range between 1,618 mm in Hawaii and 241 mm in Nevada. For the entire USA, excluding Hawaii and Alaska, the average amount of rainfall is 767 mm.[3]
Hydrology	The nation's largest river systems based on flow volume are the Columbia River in the north-west and the Mississippi River in the south-east.

Electricity sector overview

In 2017, total electricity generating capacity in the USA was 1,084,783 MW, of which hydropower (including pumped storage) accounted for 8.5 per cent (Figure 1).[4] In 2017, annual generation was approximately 4,000 TWh. Natural gas was the largest source (32 per cent), followed by coal (30 per cent), nuclear (20 per cent) and hydropower (7 per cent) (Figure 2).[5]

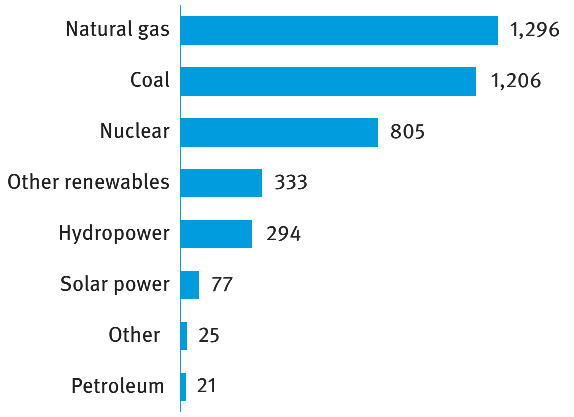
Figure 1.
Installed electricity capacity by source in the USA (GW)



Source: EIA[4]

For many years, coal has been the largest single source of electricity supply, although recently natural gas generation has been growing rapidly, along with wind and solar. Hydropower, as a percentage of total electricity generation, has been relatively stable. In general, electricity load growth has been minimal, notwithstanding economic growth, as the economy becomes more energy efficient. The electrification rate is 100 per cent.

Figure 2.
Annual electricity generation by source in the USA (GWh)



Source: EIA[5]

Historically, the electricity industry of the USA has been comprised of a mix of private and public utilities that generate and deliver electricity to customers within exclusive franchise service territories. Currently, more than 3,000 electric utilities operate across the country. More recently, some states and regions have established competitive markets for both electricity generation and delivery. This process is often referred to as electric industry restructuring or deregulation and has resulted in new entrants to all segments of the electricity industry, including generation, transmission and delivery. The move toward greater competition in electricity supply and delivery has fostered a shift in electricity generation sources.

Because of the historically exclusive nature of utility service territories, the electric industry has been subject to a high degree of Governmental regulation. Investor-owned utilities are regulated by the states in which they operate. Municipal utilities are operated by local governments and are overseen by local elected or appointed officials. Electric cooperatives are governed by a board of directors elected from the cooperative's membership.

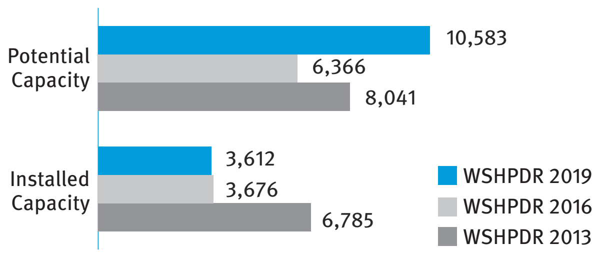
In addition, the Federal Energy Regulatory Commission (FERC), an independent agency of the US Government, regulates the interstate transmission of electricity. Independent System Operators (ISOs) administer the transmission grid on a regional basis, including some portions of Canada. These entities were established to provide non-discriminatory access to transmission for both electricity generators and distribution companies in competitive markets. The ISOs also perform centralized day-ahead dispatch of the generation resources in their service area to produce a least-cost production schedule for each hour of the next day, resolve gaps between generation and demand in real time and operate ancillary service markets. The USA-based ISOs are regulated by the FERC.

Electricity tariffs are a product of a utility's generation, transmission, distribution and administrative costs, as well as return on investment in the case of investor-owned utilities. Recent electricity rates have been relatively stable with low annual growth, partly in response to low wholesale prices resulting from an abundance of natural gas. In 2017, average electricity prices were: 0.129 US$ /kWh for residential consumers, 0.107 US$/kWh for commercial consumers and 0.691 US$/kWh for industrial consumers.[6]

Small hydropower sector overview

There is no widely agreed-upon definition of small hydropower (SHP) in the USA. However, for this report, SHP is defined as hydropower plants with an installed capacity of up to 10 MW.

Figure 3.
Small hydropower capacities 2013/2016/2019 in the USA (MW)



Source: Uria-Martinez et al.,[7] Kao,[8] Hadjerioua et al.,[9] Bureau of Reclamation,[10] Pulskamp,[11] Kao & Johnson,[12] *WSHPDR 2016*,[13] *WSHPDR 2013*[14]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

The total SHP capacity as of 2017 was 3,612 MW with an estimated potential for at least an additional 6,971 MW indicating that approximately 34 per cent of the total technical potential has been developed.[7,8,9,10,11,12] In comparison to data from the *World Small Hydropower Development Report* (*WSHPDR*) *2016*, installed capacity decreased by less than 2 per cent, while potential increased by 66 per cent (Figure 3).

The hydropower generating capacity of the USA (including projects of all sizes and excluding pumped storage hydropower) increased by 2,042 MW from 2007 to 2017, bringing installed capacity to 80.09 GW across 2,248 separate plants.[15] Of this net increase, almost 70 per cent resulted from refurbishments and upgrades to the existing fleet. Most of the 117 new hydropower plants that have started operation since 2007 involved additions of hydropower generation equipment to non-powered dams (NPDs) (38) or conduits (74). The median size of new plants is less than 10 MW.[7]

Roughly half of US hydropower capacity is located in three states – Washington, Oregon and California.[7] Three federal agencies, the US Army Corps of Engineers (USACE), the US Bureau of Reclamation (Reclamation) and the Tennessee Valley Authority, own nearly half of the US hydropower capacity. Most of the installed hydropower capacity comes from large projects built between 1930 and 1970. Since the 1980s, most new hydropower capacity additions have been small.[15]

As of 2017, the existing fleet of US small hydropower plants consisted of 1,646 plants with a combined generating capacity of approximately 3,612 MW.[7] The Northeast and the Southwest are the two regions with the highest number of small hydropower facilities (537 and 434, respectively). On average, the small hydropower fleet generated 13,804 GWh per year for the period 2007–2017, approximately 5 per cent of total US hydropower generation.[7]

Potential new hydropower resources in the United States are classified into three categories – non-powered dams (NPDs), new stream-reach development (NSD) and conduits. A national assessment of the capacity and energy potential realized from the addition of hydropower to NPDs identified 397 dams with technical potential capacities in the 1 MW–10 MW range. The total estimated technical potential capacity for NPDs under 10 MW is approximately 2,500 MW. Their combined annual technical potential is 4,777 GWh.[9]

A national assessment of NSD resources published in 2014 identified a potential technical capacity of 4,321 MW across 1,035 sites with estimated project sizes of less than 10 MW. The annual generation potential of these projects was estimated at 23,374 GWh.[8]

There has not yet been a comprehensive federal resource assessment of conduit hydropower, although some state and federal agencies have started to compile relevant data. A 2012 study by the Bureau of Reclamation (otherwise known as simply Reclamation) examined the energy development potential at Reclamation-owned facilities.[10] That study and a related supplement found that 191 Reclamation canals had at least some level of hydropower potential and that 70 of those sites could be considered economically viable for development. This report concluded that there is 104 MW of potential capacity and 365 GWh of potential annual generation at the 373 Reclamation canals studied.[11]

In 2018, Oak Ridge National Laboratory developed a methodology for analysis of the untapped hydropower generation potential of public water systems.[12] A total of approximately 12 MW of potential conduit hydropower capacity was estimated in Oregon and 34 MW in Colorado. Their corresponding annual hydroelectricity supply is estimated to be 65 GWh/year in Oregon and 202 GWh/year in Colorado.

As of the end of 2017, the US hydropower "pipeline" of planned projects contained 214 projects with a combined capacity of 1,712 MW. Of these, 165 were small projects with a total combined capacity of 420 MW. The majority of planned new small hydropower projects involve adding hydropower generation to existing dams or conduits (159 projects with a combined capacity of 396.5 MW). Only six projects would develop new stream-reaches. The median capacities of small NPD and NSD projects are 4 MW and 5 MW, respectively. The median capacity of conduit projects is significantly smaller (0.42 MW). The Southwest is the leading region by the number of planned projects but ranks last in terms of proposed capacity. Most planned small hydropower capacity in the Southwest involves the addition of generation capacity to existing irrigation and water supply conduits. Such projects are typically smaller than NPD or NSD sites. Most proposed development is undertaken by private entities. Within the public category, most developers are municipalities (16 projects) or irrigation and water supply districts (42).[7]

Projects in the Pending Permit and Issued Permit stages are undergoing feasibility evaluations. Attrition rates are high at these early stages of the development process. A project with a Pending Application has submitted an application for a federal permit. Projects with Issued Authorizations have already received their federal authorization and are more likely to proceed to construction. However, obtaining additional permits at the state or local level, finalizing engineering designs, negotiating power purchase agreements and finalizing project financing are additional necessary steps before starting construction that usually take place at the Issued Authorization stage. These additional steps often pose challenges for small project developers, resulting in delays and cancellations of projects, so it is difficult to predict what percentage of the 62 small projects with Issued Authorizations, totalling 125 MW, will complete construction.

Renewable energy policy

The Public Utilities Regulatory Policy Act (PURPA), which became law in 1978, introduced competition into the US electric power industry, particularly in the generation sector. PURPA conferred special rates and regulatory treatment on a new class of generators known as qualifying facilities (QFs). These consist of co-generation facilities and small power production facilities, with the latter defined as facilities generating 80 MW or less using a renewable energy source (i.e., hydropower, wind power, solar power, biomass, waste or geothermal power).[16] PURPA required electric utilities to interconnect with and purchase power from QFs at the utility's "avoided cost," defined as the cost that the utility would otherwise incur in either generating the power itself or procuring power from other sources.

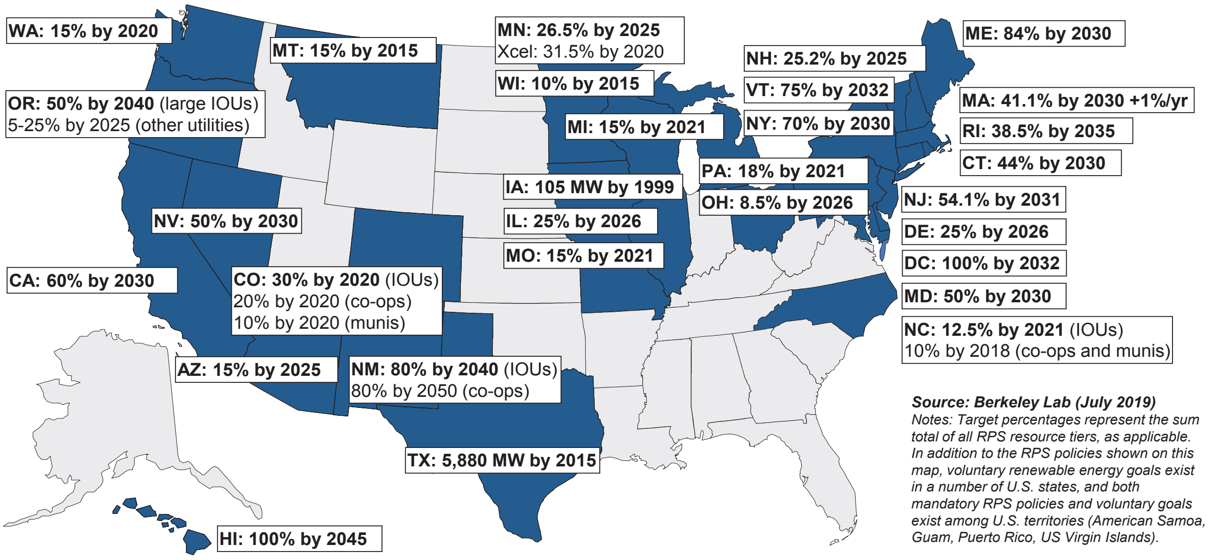
With the Energy Policy Act of 2005, Congress made an important modification to PURPA, lessening PURPA's mandatory purchase obligation if FERC determines that QFs have non-discriminatory access to the market. In this context, FERC determined that an ISO generally provides a sufficiently competitive market structure to support elimination of the PURPA purchase requirement for utilities operating within the ISO. At the same time, however, FERC established that "small QFs" do not have non-discriminatory access to wholesale markets. Therefore, the PURPA purchase obligation for utilities remains in force for small QFs, making it possible for small hydropower generators to secure utility power purchase agreements.[17] In May of 2018, FERC announced that it would launch a review of PURPA to examine issues involved in PURPA implementation and ways to address them.

The federal Government also provides tax incentives to spur renewable energy development, including the production and investment tax credits. Both of these expired at the end of 2016 for hydropower but are still available for other renewable energy technologies through 2021. Small hydropower has also been eligible for federal accelerated depreciation tax treatment, and some states offer tax incentives and exemptions.

Individual US states have adopted policies to encourage renewable energy development. The most prominent of these policies has been the adoption of a renewable portfolio standard (RPS). An RPS is a market-based policy that requires electric utilities and other retail electricity suppliers to supply a minimum percentage of their electricity sales from eligible renewable energy sources. As of July 2017, 29 states and the District of Columbia had instituted RPS policies, covering 56 per cent of total US retail electricity sales (Figure 4).[18] Significant RPS-related policy revisions in recent years include increased RPS targets for many states. In 2018, the California legislature approved legislation calling for California electric utilities to provide electricity using 100 per cent clean energy by 2045.

Small hydropower projects are typically RPS eligible, whereas large hydropower projects are often excluded from RPS eligibility. Common hydropower restrictions for RPS eligibility include those based on capacity, type and environmental sustainability criteria. One environmental standard is the Low Impact Hydropower Institute certification standard, used for RPS eligibility in a variety of states.[19] Many RPS policies also have vintage requirements, such as for "new" development, which can disqualify hydropower production from RPS eligibility.

Figure 4.
Status of RPS policies in the USA, July 2019



Source: Lawrence Berkeley National Laboratory[18]

Small hydropower projects are typically RPS eligible, whereas large hydropower projects are often excluded from RPS eligibility. Common hydropower restrictions for RPS eligibility include those based on capacity, type and environmental sustainability criteria. One environmental standard is the Low Impact Hydropower Institute certification standard, used for RPS eligibility in a variety of states.[19] Many RPS policies also have vintage requirements, such as for "new" development, which can disqualify hydropower production from RPS eligibility.

A feed-in tariff (FIT) is another policy that some states and utilities have adopted to incentivize electricity procurement from smaller renewable energy generators. A small hydropower system installed adjacent to a local electricity load can typically take advantage of net energy metering (NEM). Most US states have some form of NEM requirement, providing a potent economic incentive for distributed renewable energy generation, including small hydropower.[20]

In recent years, Congress has provided record levels of funding for the Department of Energy (DOE) hydropower programme. For fiscal year 2018, DOE received US$105 million. Of this total, US$70 million is directed to support marine and hydrokinetic energy programmes, and US$35 million will support the hydropower and pumped storage programme, some of which supports small hydropower. In August 2018, DOE's Water Power Technology Office announced up to US$9 million in funding for innovative design concepts for standard modular hydropower and pumped storage hydropower. The first topic area in the funding opportunity seeks to stimulate innovative design concepts for small, low-head hydropower plants capable of lowering capital costs and reducing the environmental impacts of development at NSD sites.

Legislation on small hydropower

Developers of small hydropower facilities need to follow different approval processes depending on ownership, project type, and other project attributes. Most projects require a FERC licence or exemption from licensing. Although the exemption process is typically shorter than the licensing process, they both typically take multiple years. Seeking authorization for development of hydropower at USACE-owned dams involves obtaining a Section 408 approval from USACE in addition to a FERC licence. Typically, the two processes have been implemented sequentially, with most of the work needed to obtain USACE approval taking place after a FERC licence was issued. Securing federal authorization for development of hydropower at Reclamation-owned dams does not typically involve FERC, but rather a Lease of Power Privilege process.[21]

The Hydropower Regulatory Efficiency Act of 2013 introduced a quicker, easier pathway to regulatory approval for the subset of projects involving the addition of hydropower to non-federal conduits (typically, existing pipelines and canals) with capacities of less than 5 MW. A developer for one of these projects needs to notify FERC of the intention to construct a hydropower facility. It will typically receive "qualifying conduit" status, completing the federal approval process, within 60 days unless FERC or the public contest the project's ability to meet the eligibility criteria.

In October of 2018, Congress passed the America's Water Infrastructure Act, legislation which included provisions to help streamline federal regulatory approval processes for hydropower. The bill shortens, from 60 to 45 days, the FERC process for qualifying conduit determination required by the 2013 Hydropower Regulatory Efficiency Act and replaces the

5 MW cap on qualifying conduit hydropower with a 40 MW cap. The bill also requires FERC to establish an expedited licensing process for NPD projects that will shorten the FERC decision timeframe for licence applications to 2 years or less. The bill also requires FERC, USACE and the US Department of the Interior to develop a list of existing federal NPDs that have the greatest potential for hydropower development.

A US Department of Energy (DOE)-administered federal incentive programme supports the development of new small hydropower projects at existing dams or conduits. In 2014, Congress provided the initial funding allocation for the Section 242 Programme, a hydropower incentive programme that was created through the Energy Policy Act of 2005. The programme has received congressional appropriations every year since 2014. Facilities can receive up to US$750,000 per year for up to 10 years, subject to availability through ongoing congressional appropriations. The programme's incentive payments are paid on a per-kilowatt-hour-generated basis, with payment amounts depending upon overall programme participation. The programme's incentive payments have ranged from 0.009 US$/kWh to 0.015 US$/kWh. Although congressional authorization for the Section 242 Programme expired in 2015, already-participating hydropower facility owners are allowed to receive up to 10 years of payments, provided that congressional appropriations continue to fund the programme. Legislation also has been introduced in the Congress to reauthorize the Section 242 Programme beyond its initial 10-year authorization, which would enable projects built after 2015 to also become eligible for 242 Programme incentive payments.

Some states have created programmes and policies specifically to financially support the development of small hydropower.[22] For example, in California some types of small hydropower projects are eligible for incentive funding through the state's Self-Generation Incentive Programme. Colorado provides US$15,000 feasibility grants for eligible entities, as well as low-interest (2 per cent), long-term (30-year) loans that can fund project construction. Oregon provides financial assistance to small hydropower developers through the Energy Trust of Oregon.

Barriers to small hydropower

Small hydropower is the most cost-effective type of new hydropower development available in the United States because it typically uses existing infrastructure, including existing NPDs, canals and pipelines. Record federal support for hydropower, along with recent legislative reforms, may help small hydropower achieve its substantial untapped potential. However, developers of new small hydropower may still face some challenges, including those described below.

- *Regulatory approval challenges*. Developing new hydropower projects has proved challenging in recent decades because of uncertain federal regulatory processes that have made it difficult for public- and private-sector investors to obtain long-term, low-cost financing to support project development.
- *Market challenges.* In addition to the challenge posed by market competition from other electricity generating technologies (including natural gas, wind and solar power), hydropower's full value to the electric grid in terms of ancillary services and operational flexibility typically is not financially compensated in the current US electricity market.
- *Lack of comprehensive information regarding potential conduit sites*. Although federal agencies have completed nationwide hydropower resource assessments for existing NPDs and NSD, a comprehensive national assessment regarding conduit opportunities has not been undertaken. These include water supply pipelines, which represent perhaps the most economically feasible type of new hydropower development because they can typically take advantage of higher energy value available through NEM.[23]
- *Risk aversion regarding new technology*. Existing dam and conduit owners are typically cautious and risk-averse with respect to the water systems for which they are responsible, making it difficult for them to recognize opportunities to develop hydropower project sites. Furthermore, many water agencies have no understanding of available small hydropower technologies. Newer, more cost-effective small hydropower technologies do not typically have long operational track records, making potential investors shy away from adopting them.
- *Lack of standardized technology*. Almost every hydropower project is custom engineered, presenting associated high engineering costs because each project is site specific.
- *Electrical interconnection.* Uncertainty in the cost, timing and technical requirements of grid interconnection can be challenging for small hydropower and other distributed energy resources because interconnection processes can be expensive and time consuming.
- *Electrical inspection*. Because very few small hydropower projects are installed each year, most electrical inspectors are not familiar with them. Therefore, it can be difficult to secure electrical inspection approval for very small plants that are net metered. Small hydropower is not addressed in the National Electrical Code. Furthermore, the US small hydropower industry is not yet large enough to support the mass manufacturing of standardized products that have completed independent certification. Costs associated with post-manufacture, in-the-field product testing and approval to ensure product safety can adversely affect a project's economic feasibility.
- *State and local policy issues.* Challenges to small hydropower development can come from state and local regulatory policies, including regulatory issues associated with water quality certifications and other state and local environmental requirements.

References

1. This report was adapted from Johnson, K., Hadjerioua, B. & Uria-Martinez, R. (2018). *Small Hydropower in the United States.* Oak Ridge National Laboratory.
2. U.S. Census Bureau (2015). *Official Website.* Available from www.census.gov.
3. U.S. Climate data (n.d.). *Official Website.* Available from http://www.usclimatedata.com/.
4. U.S. Energy Information Administration (EIA) (n.d.). *Table 4.3. Existing Capacity by Energy Source, 2017.* Available from https://www.eia.gov/electricity/annual/html/epa_04_03.html
5. U.S. Energy Information Administration (EIA) (n.d.). *Table 3.1.A. Net Generation by Energy Source: Total (All Sectors), 2007-2017.* Available from https://www.eia.gov/electricity/annual/html/epa_03_01_a.html
6. U.S. Energy Information Administration (EIA) (2018). *Short Term Energy Outlook,* Washington, DC.
7. Uria-Martinez, R. et al. (2018). 2017 Hydropower Market Report. Available from https://www.energy.gov/sites/prod/files/2018/04/f51/Hydropower%20Market%20Report.pdf
8. Kao, S.C. et al. (2014). *New Stream-reach Development: A Comprehensive Assessment of Hydropower Energy Potential in the United States*, GPO DOE/EE-1063, Wind and Water Power Program, US Department of Energy, Washington, DC
9. Hadjerioua, B., Wei, Y. and Kao, S.-C. (2012). *An Assessment of Energy Potential at Non-powered Dams in the United States*, GPO DOE/EE-0711, Wind and Water Power Program, Department of Energy, Washington DC
10. U.S. Bureau of Reclamation (2012). *Site Inventory and Hydropower Energy Assessment of Reclamation-owned Conduits.* Supplement to *Hydropower Resource Assessment at Existing Reclamation Facilities*, US Bureau of Reclamation, US Department of the Interior
11. Pulskamp, M. (2012). *Site Inventory and Hydropower Energy Assessment of Reclamation-owned Conduits*. Supplement to *Hydropower Resource Assessment at Existing Reclamation Facilities*, US Bureau of Reclamation, Denver, CO, March 2012.
12. Kao, S.-C. and Johnson, K. (2018). *An Assessment of Energy Potential at Public Drinking Water Systems: Initial Report on Methodology,* ORNL/TM-2018/869, Oak Ridge National Laboratory, Oak Ridge, TN, July 2018
13. CHENG, X., Singh, P. R., WANG, X., and Kremere, E., eds. (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
14. LIU, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013.* United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www.smallhydroworld.org
15. US Department of Energy (DOE) (2016). *Hydropower Vision—A New Chapter for America's 1st Renewable Electricity Source*, Washington DC
16. Federal Energy Regulatory Commission (FERC) (n.d.). *What is Qualifying Facility?* Available from http://www.ferc.gov/industries/electric/gen-info/qual-fac/what-is.asp
17. Federal Energy Regulatory Commission (FERC) (2006). *Order No. 688.* Available from https://www.ferc.gov/whats-new/comm-meet/101906/E-2.pdf
18. Lawrence Berkeley National Laboratory (2019). *Renewables Portfolio Standards Resources.* Available from http://emp.lbl.gov/rps
19. Low Impact Hydropower Institute (n.d.). *Official website.* Available from See http://www.lowimpacthydro.org
20. DSIRE (n.d.). Database of State Incentives for Renewables & Efficiency. Available from http://www.dsireusa.org/
21. Reclamation (n.d.). *Hydropower Program. Lease of Power Privilege (LOPP).* Available from https://www.usbr.gov/power/LOPP/
22. Curtis, T., Levine, A. and Johnson, K. (2017). *State Models to Incentivize and Streamline Small Hydropower Development,* NREL/TP-6A20-70098, National Renewable Energy Laboratory, Golden, CO, 2017
23. Johnson, K., Levine, A. and Curtis, T. (2018). *Energy Recovery Hydropower: Prospects for Off-Setting Electricity Costs for Agricultural, Municipal, and Industrial Water Providers and Users. July 2017–September 2017*, NREL/TP-6A20-70483, National Renewable Energy Laboratory, Golden, CO, January 2018

Contributing organizations

Laboratoire de Génie Électrique d'Oran (LGEO)

Université des sciences et de la technologie d'Oran – Mohamed Boudiaf (USTO-MB)

Guakía Ambiente

Scientific Research Institute of Energy (SRIE)

Kleinwasserkraft Österreich

Pöyry

Jimma University

France Hydro Électricité

Ea Energy Analyses

Guyana Energy Agency (GEA)

La Asociación Hondureña de Energía Renovable (AHER)

The International Energy Agency Technology Cooperation Programme on Hydropower (IEA Hydro)

International Network on Small Hydro Power (INSHP)

Komite Nasional Indonesia untuk Bendungan Besar (KNI-BB) / National Committee on Large Dams (INACOLD)

Catalytic Innovations

Ministère de l'Energie, de l'Eau et des Hydrocarbures (MEEH) de Madagascar

Universiti Kuala Lumpur (UniKL)

University of Mauritius

Agenția pentru Eficiență Energetică (AEE) / Agency for Energy Efficiency, Moldova

Universidade Eduardo Mondlane

IHE Delft Institute for Water Education

Asociacion de Trabajadores de Desarrollo Rural – Benjamin Linder (ATDER-BL)

The European Bank for Reconstruction and Development (EBRD)

Energetyka Wodna

Hangzhou Regional Center (Asia-Pacific) for Small Hydro Power (HRC)

Der Wasserwirt

Ping An Bank

Sarhad Rural Support Programme (SRSP)

Smart Hydro Power

La Organización Latinoamericana de Energía (OLADE)

SMEC - Engineering General Consultants EGC (Pvt) Ltd.

Centro de Investigaciones Hidráulicas e Hidrotécnicas (CIHH)

Universidad Tecnológica de Panamá (UTP)

Towarzystwo Rozwoju Małych Elektrowni Wodnych (TRMEW)

Faculdade de Ciências e Tecnologia (FCT), Universidade Nova de Lisboa

Programa de Pequeños Subsidios (SGP) del FMAM República Dominicana

Université Cheikh Anta Diop de Dakar (UCAD)

Slovak University of Technology in Bratislava (STU) - Faculty of Electrical Engineering and Information Technology (FEI)

One Earth Future Foundation

Sri Lanka Sustainable Energy Authority (SLSEA)

Sudan Energy Research Institute (ERI)

École Polytechnique Fédérale de Lausanne (EPFL)

University of Dar es Salaam (UDSM)

Faculté des Sciences Economiques et de Gestion de Sfax (FSEGS)

Kocaeli Üniversitesi

NEWPLAN Group Ltd

Institute of Renewable Energy of the National Academy the Sciences of Ukraine

The Economic Community of West African States (ECOWAS) Centre for Renewable Energy and Energy Efficiency (ECREEE)

Zhaoheng Hydropower Group

HYCON GmbH

Turbulent

Virunga Power

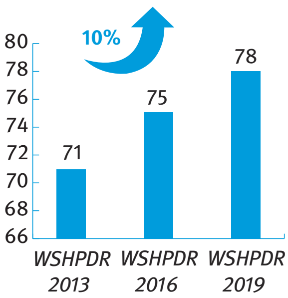
Universidad de Murcia

Platform of Hydraulic Constructions (PL-LCH)

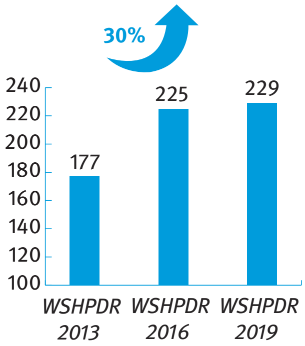
World Small Hydropower Development Report 2019

The ***World Small Hydropower Development Report (WSHPDR) 2019*** is an update of the Report's first two editions in 2013 and 2016. The *WSHPDR 2019* contains 166 national reports and 20 regional reports, with 21 new countries added since the first edition.

World SHP installed capacity (GW)



World SHP potential (GW)



- The Report is available on **www.smallhydroworld.org;**
- More than 230 experts and organizations have been involved;
- The Report covers **20 regions and 166 countries**;
- Every country report provides information on:
  a) Electricity sector;
  b) Small hydropower sector;
  c) Renewable energy policy and;
  d) Barriers to small hydropower development.

A special report with **Case Studies** is added to the *WSHPDR 2019*, showing the different roles small hydropower can play in achieving the SDGs.

Small hydropower for a better world

- SHP for productive use;
- SHP for social and community development;
- SHP financing;
- Technology, innovation and smart SHP;
- Incentive policies for SHP development;
- Green SHP.

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Vienna International Centre
P.O. Box 300 · 1400 Vienna · Austria
Tel.: (+43-1) 26026-0
E-mail: renewables@unido.org
www.unido.org

INTERNATIONAL CENTER
ON SMALL HYDROPOWER

136 Nanshan Road
Hangzhou · 310002 · P.R.China
Tel.: (+86-571) 87132780
E-mail: report@icshp.org
www.icshp.org