UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

INTERNATIONAL CENTER
ON SMALL HYDROPOWER

World Small Hydropower Development Report 2022

South America

Disclaimer

The World Small Hydropower Development Report 2022 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.

Suggested citation:

UNIDO, ICSHP (2022). *World Small Hydropower Development Report 2022*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR2022.

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

The digital copy is available at www.unido.org/WSHPDR2022.

Design: red not 'n' cool
Cover Picture: depostihphotos

Table of Content

Acknowledgements

The World Small Hydropower Development Report 2022. was prepared under the overall guidance of Tareq Emtairah, Director of the Division of Decarbonization and Sustainable Energy, Petra Schwager-Kederst, Chief of the Division of Climate and Technology Partnerships at the United Nations Industrial Development Organization (UNIDO) and LIU Deyou, Director General of the International Center on Small Hydropower (ICSHP).

The preparation of this thematic publication was headed by LIU Heng, Senior Technical Advisor at UNIDO and consulted by HU Xiaobo, Chief of the Division of the Multilateral Development at ICSHP. The work was coordinated by Oxana Lopatina at ICSHP and Eva Krēmere at UNIDO. The publication is the result of three years of intense research work 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

WSHPDR2022 team

Head	LIU Heng — Senior Technical Advisor, United Nations Industrial Development Organization (UNIDO)
Coordinators	Oxana Lopatina — International Center on Small Hydro Power (ICSHP)
	Eva Krēmere — United Nations Industrial Development Organization (UNIDO)
Team	UNIDO: Eva Krēmere, Sanja Komadina. Interns: LIU Fangjie, REN Wenxuan
	ICSHP: HU Xiaobo, Oxana Lopatina, Danila Podobed, Alicia Chen Luo, Veronika Spurna, Tamsyn Lonsdale-Smith, Bilal Amjad, Oluwatimilehin Paul Olawale-Johnson, Davy Rutajoga, Laura Stamm, YUAN Ruize, BAO Lina, ZHANG Yingnan, DING Yan

Editorial Board

Jesse Benjaman (PCREEE), Alfonso Blanco-Bonilla (OLADE), Cristina Diez Santos (Open Hydro), Tareq Emtairah (UNIDO), Geraldo Lúcio Tiago Filho (CERPCH), Guei Guillaume Fulbert Kouhie (ECREEE), Dirk Hendricks (EREF), Wim Jonker Klunne (Hydro4Africa), Arun Kumar (IIT Roorkee), LIU Deyou (ICSHP), LIU Heng (UNIDO), LIU Hongpeng (UNESCAP), Eddy Moors (IHE Delft Institute for Water Education), Niels Nielsen (Kator Research Services), Mohamedain Seif Elnasr (COMESA), María Ubierna (Open Hydro), XING Yuanyue (Ministry of Water Resources of China)

Peer Reviewers

Joan Cecilia C. Casila, Choten Duba, Mohammad Hajilari, Michela Izzo, Annabel Johnstone, Dimitar Kisliakov, Wim Jonker Klunne, Arun Kumar, Sarah Kwach, Kristian Dahl Larsen, Charlene Monaco, Niels Nielsen, Victor Odundo Owuor, Emanuele Quaranta, Nicolae Soloviov, Fujimoto Tokihiko, Leandro Zelaya

Contributing Experts

Arturo Alarcon, Sameer Algburi, Alsamaoal Almoustafa, Gabrial Anandarajah, Vicky Ariyanti, Fredrick Arnesen, Engku Ahmad Azrulhisham, Ayurzana Badarch, BAO Lina, Mathieu Barnoud, Alexis Baúles, Sow Aissatou Billy, Alaeddin Bobat, Frank Charles Ramírez Bogovich, Ejaz Hussain Butt, Abou Kawass Camara, Jose Campos, Joan Cecilia C. Casila, Piseth Chea, Julian Chin, Salim Chitou, Gift Chiwayula, Brenda Musonda Chizinga, Nouri Chtourou, Romao Grisi Cleber, Ryan Cobb, Poullette Faraon Chaul Corona, John Cotton, Slobodan Cvetkovic, Manana Dadiani, Asger Dall, Bassam Al Darwich, Denise Delvalle, Tobias Dertmann, Gabriel Chol Dhieu, Jonas Dobias, Aurélie Dousset, Choten Duba, José Rogelio Fábrega Duque, Nadia Eshra, Cayetano Espejo Marín, Paola Estenssoro, Soukaina Fersi, Geraldo Lúcio Tiago Filho, Danilo Fras, Fujimoto Tokihiko, Patrick Furrer, Camila Galhardo, Ramón García Marín, Adnan Ghafoor, Gaëlle Gilboire, Zelalem Girma, Mohammad Hajilari, Geon Hanson, Richard Hendriks, Mabikana Voula Boniface Hervé, Yan Huang, Chinedum Ibegbulam, Michela Izzo, Jamal Jaber, Gordana Janevska, Sergio Armando Trelles Jasso, Rim Jemli, Marco Antonio Jimenez, Annabel Johnstone, Julien Jomaux, Wim Jonker Klunne, Abdoul Karim Kagone, John K. Kaldellis, Bryan Karney, Raul Pablo Karpowicz, Egidijus Kasiulis, Shorai Kavu, Eleonora Kazakova, Joseph Kenfack, Dong Hyun Kim, George Kimbowa, Dimitar Kisliakov, Maris Klavins, Ioannis Kougias, Rastislav Kragic, Arun Kumar, Sarah Kwach, Kristian Dahl Larsen, Seung Oh Lee, Jean-Marc Levy, Bryan Leyland, Laura Lizano, Galina Livingstone, Kimberly Lyon, Sarmad Nozad Mahmood, Ewa Malicka, Pedro Manso, Andrés Teodoro Wehrle Martínez, Anik Masfiqur, Mareledi Gina Maswabi, Hamid Mehinovic, Juan José García Méndez, Luiza Fortes Miranda, Guram Mirinashvili, Julio Montenegro, Bastian Morvan, Reynolds Mukuka, Béla Munkácsy, Patricio Muñoz, Wakati Ramadhani Mwaruka, Thet Myo, N'guessan Pacôme N'Cho, Sea Naichy, Niels Nielsen, Gilbert Nzobadila, Emna Omri, Karim Osseiran, Sok Oudam, Victor Odundo Owuor, Grant Pace, Aung Thet Paing, Hok Panha, Sotir Panovski, Ahmet Penjiev, Georgy Petrov, Alexandra Planas, Bogdan Popa, Cecilia Correa Poseiro, Sunil Poudel, Ravita D. Prasad, Kenneth Bengtson Tellesen Primdal, Leonardo Peña Pupo, Thoeung Puthearum, Emanuele Quaranta, Samira Rasolkhani, Atul Raturi, Thomas Buchsbaum Regner, António Carmona Rodrigues, Jorge Saavedra, Najib Rahman Sabory, Victor Sagastume, Esmina Sahic, Alberto Sanchez, Karine Sargsyan, Vahan Sargsyan, Goran Sekulić, Ozturk Selvitop, Shamsuddin Shahid, Stafford W. Sheehan, Manish Shrestha, Sangam Shrestha, Mundia Simainga, Gjergji Simaku, Martin Sinjala, Seming Skau, Nicolae Soloviov, Amine Boudghene Stambouli, Dmytro Stefanyshyn, Pavel Štípský, Jean Sumaili, Dinesh Surroop, Areli Sutherland, Alberto Tena, Pierre Kenol Thys, Anastasiya Timashenok, Panagiotis Triantafyllou, Alexander Urbanovich, Joelinet Vanomaro, Goran Vasilic, Ciza Willy, Ernesto Yoel Fariñas Wong, Gendensuren Yondongombo, Saida Yusupova

South America

Countries: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, French Guiana, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela

INTRODUCTION TO THE REGION

Electricity generation in South America is dominated by thermal power and large hydropower. Brazil is the largest electricity producer in South America and accounts for approximately half of the region's total installed capacity and 60 per cent of the installed hydropower capacity. Brazil, Argentina, Chile, Peru and Uruguay all have highly diversified electricity sectors with significant installed capacities of solar power, wind power, bioenergy and other renewable energy sources (RES) supplementing hydropower and thermal power capacities. In addition, Brazil and Argentina operate the only nuclear power plants in the region. Other countries in South America rely primarily on a mix of hydropower and thermal power, with RES other than hydropower playing a relatively minor role.

Hydropower plays a particularly prominent role as the single largest source of electricity generation in Brazil, Colombia, Ecuador, Paraguay, Peru and Uruguay. In Paraguay, hydropower accounts for nearly 100 per cent of installed capacity and annual electricity generation and enables the country to export more than half of its annual electricity production to Brazil and Argentina. In other countries in the region, thermal power is the dominant energy source, while hydropower plays a supplementary role, with the exception of Guyana, where the installed capacity and annual generation of hydropower are negligible. Under the framework of the Renewables in Latin America and the Caribbean (RELAC) initiative, 12 countries in the region have committed to achieving a 70 per cent share of renewable energy sources in the regional energy mix by 2030, with hydropower expected to play a key role. Brazil is expected to continue to dominate the hydropower sector of South America through the current decade.

Electricity access is high across South America, at or approaching 100 per cent in most countries in the region. There is a high degree of cooperation among countries in cross-border power transmission and generation of electricity. For example, Bolivia, Chile, Colombia, Ecuador and Peru participate in the Andean Interconnection System (SINEA), which aims to integrate the regulatory frameworks, interconnections and electricity markets of the member states, while Paraguay operates several hydropower plants jointly with Brazil and Argentina.

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

Table 1. **Overview of South America**

Country	*Total population (million people)*	*Electricity access, total (%)*	*Electricity access, rural (%)*	*Total installed capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower installed capacity (MW)*	*Hydropower generation (GWh/year)*
Argentina	45	100	100	41,952	134,177	11,344	30,350
Bolivia	12	88	72	3,484	9,531	1,073	3,251
Brazil	212	100	100	177,300	626,300	109,315	397,900
Chile	19	N/A	N/A	26,653	70,828	6,806	18,263
Colombia	48	97	83	17,432	69,324	11,893	49,837
Ecuador	18	100	100	8,725	31,248	5,099	24,875
French Guiana	0.3	N/A	N/A	340	906	118	535
Guyana	1	92	90	348	1,134	0.02	N/A
Paraguay	7	100	100	8,816	46,373	8,810	46,371
Peru	33	N/A	N/A	15,371	49,187	5,551	29,318
Suriname	1	98	96	502	2,368	189	1,105
Uruguay	3	100	99	4,920	16,088	1,538	8,108
Venezuela	28	100	100	34,165	109,000	16,228	N/A
Total	-	-	-	**340,008**	-	**177,964**	-

Source: *WSHPDR 2022*[1]

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

REGIONAL SMALL HYDROPOWER OVERVIEW

The definition of small hydropower (SHP) in South America varies from country to country. The up to 10 MW definition is used in Ecuador and French Guiana, while Bolivia and Guyana have both adopted the up to 5 MW definition in line with the definition proposed by the Latin American Energy Organization (OLADE). For other countries in the region, the definition of SHP includes larger plants. Chile, Colombia and Peru define SHP as plants of up to 20 MW, Brazil uses the up to 30 MW definition, and Argentina, Paraguay and Uruguay use the up to 50 MW definition. No official definition of SHP exists in Suriname or Venezuela.

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

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

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed capacity (≤10 MW)*	*Potential capacity (≤10 MW)*
Argentina	Up to 50 MW	510.0	N/A	97.0	430.0
Bolivia	Up to 5 MW	N/A	N/A	99.1	99.1*
Brazil	Up to 30 MW	6,324.6	35,765.0	1,608.2	3,737.8
Chile	Up to 20 MW	618.0	5,145.0	304.0	2,995.0
Colombia	Up to 20 MW	900.8	N/A	234.6	4,946.0
Ecuador	Up to 10 MW	112.7	356.3	112.7	356.3
French Guiana	Up to 10 MW	5.5	34.5	5.5	34.5
Guyana	Up to 5 MW	0.02	24.2	0.02	92.0
Paraguay	Up to 50 MW	0.0	116.3	0.0	N/A
Peru	Up to 20 MW	503.8	3,500.0	N/A	N/A
Suriname	N/A	N/A	N/A	0.0	2.7
Uruguay	Up to 50 MW	0.0	231.5	0.0	208.0
Venezuela	N/A	N/A	N/A	1.4	49.7
Total	-	-	-	**2,462.6**	**12,951.1**

Source: *WSHPDR 2022*[1]

Note: *Based on installed capacity.

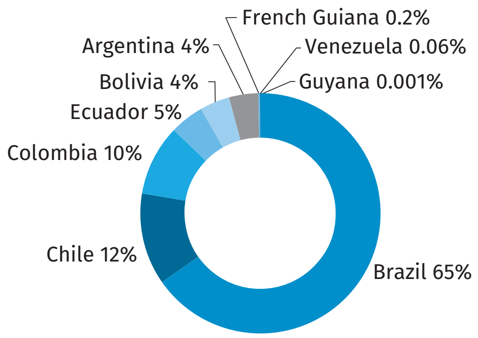
The total installed capacity of SHP of up to 10 MW in South America is 2,462.6 MW, while potential capacity is estimated at 12,951.1 MW. Relative to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity has increased by three times, mainly due to the inclusion of data on the installed capacity for SHP of up to 10 MW in Brazil. At the same time, the potential capacity has decreased by nearly 55 per cent, mainly due to a drastic downward reassessment of the SHP potential of Colombia based on more recent data.

Although hydropower potential in South America is considerable, SHP plays a relatively minor role in the electricity generation mix of most countries in the region due to heavy focus on large hydropower development, accounting for no more than 10 per cent, and usually closer to 2–5 per cent, of the countries' total installed hydropower capacities. The one exception to this pattern is Guyana, where the entire installed hydropower capacity is composed of a single micro-hydropower plant.

Brazil leads the region in installed capacity of SHP of up to 10 MW, and actively pursues SHP development both under the up to 10 MW definition as well as under the local definition of up to 30 MW. Chile, Columbia and Ecuador have also seen considerable recent expansion of SHP capacity off up to 10 MW, while Peru has dramatically increased its capacity of SHP of up to 20 MW. In other countries in the region, significant development in the SHP sector has been lacking and the reported installed SHP capacity of several countries including Bolivia, French Guiana and Suriname has decreased as a result of access to better data.

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

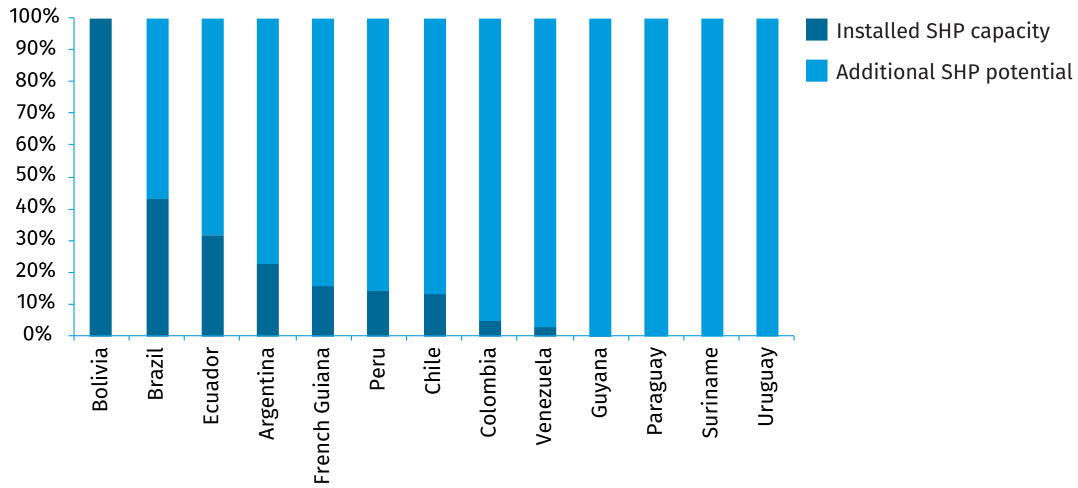
Figure 1. **Share of Regional Installed Capacity of Small Hydropower up to 10 MW by Country in South America (%)**



Source: *WSHPDR 2022*[1]

Note: Paraguay, Suriname and Uruguay are not included due to a lack of installed SHP capacity; Peru is not included due to a lack of data on SHP up to 10 MW.

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



Source: *WSHPDR 2022*[1]

Note: For SHP of up to 10 MW except in the case of Paraguay and Peru, where the local definition is used due to a lack of comprehensive data on SHP of up to 10 MW.

The installed capacity of SHP of up to 10 MW in **Argentina** is 97 MW, provided by 24 plants. The potential capacity is estimated at 430 MW, indicating that nearly 23 per cent has been developed. The SHP sector in the country has not seen any recent development and many existing SHP facilities are in need of modernization. However, several SHP projects are in the planning stages and 116 potential SHP sites have been identified.

The installed capacity of SHP of up to 10 MW in **Bolivia** is 99.1 MW. There is no reliable estimate of potential for SHP off up to 10 MW, although potential for SHP of up to 30 MW has been estimated at 200 MW. There are 13 registered SHP plants in the country, in addition to dozens of unregistered plants operating on isolated grids. Unregistered off-grid SHP plants are particularly widespread in the country's private mining sector. The Government plans to expand SHP capacity by an additional 50 MW, but suitable sites have not been comprehensively catalogued. One additional SHP plant was under construction as of 2019.

In **Brazil**, the installed capacity of SHP under the local definition of up to 30 MW is 6,324.6 MW, while the estimated potential capacity is 35,765 MW, indicating that 18 per cent has been developed. For SHP of up to 10 MW, the installed capacity is 1,608.2 MW, while potential capacity is estimated at 3,737.8 MW, indicating that 43 per cent has been developed. Development of SHP in the country is actively ongoing, with over 20 new plants commissioned in 2020 alone. Construction of new plants is carried out in accordance with targets established by the Ten-Year Plan for Energy Expansion 2029. By 2029, the Government intends to expand the country's total capacity of SHP of up to 30 MW to 9,045 MW.

The installed capacity of SHP of up to 20 MW in **Chile** is 618 MW and estimated potential capacity is 5,145 MW, indicating that 12 per cent has been developed. For SHP of up to 10 MW, the installed capacity is 304 MW and estimated potential capacity is 2,995 MW, indicating that 10 per cent has been developed. SHP development in the country is ongoing, with several new plants commissioned on average every year. Several SHP projects were ongoing as of 2021 and a number of additional projects are in the planning stages.

Colombia has an installed capacity of 900.8 MW for SHP of up to 20 MW and of 234.6 MW for SHP of up to 10 MW. The potential capacity of SHP of up to 10 MW is estimated at 4,946 MW, indicating that nearly 5 per cent has been developed. A large number of new SHP plants have been commissioned in recent years, and 43 prospective SHP projects of up to 10 MW are under review. The reported estimate of the country's SHP potential has been drastically reduced on the basis of updated, more detailed data on regional SHP potential.

The installed capacity for SHP of up to 10 MW in **Ecuador** is 112.7 MW, provided by 43 plants. Potential capacity is estimated at 356.3 MW, indicating that approximately 32 per cent has been developed. Several new SHP plants were constructed in the country between 2016 and 2020, with six additional plants expected to be completed by 2024.

French Guiana has an installed capacity of 5.5 MW for SHP of up to 10 MW, provided by two plants. The estimated potential capacity, based on plans issued by the Government for expansion of the SHP sector to 2030, is 34.5 MW, indicating that 16 per cent has been developed. Despite the established targets, little SHP development has taken place in the country in recent years, although two SHP projects are in the early planning stages.

Guyana has a single micro-hydropower plant with an installed capacity of approximately 0.02 MW. Potential SHP capacity in the country for SHP of up to 10 MW is estimated at 92 MW, which remains almost fully undeveloped. The existing SHP plant was launched in 2019 and is the first operational SHP plant in the country in over 20 years. Five projects involving the rehabilitation of non-operational SHP plants as well as the construction of new plants are in various stages of planning.

Paraguay has no installed SHP capacity, as the country's entire hydropower fleet consist of plants with installed capacities of over 50 MW. The potential capacity for SHP of up to 50 MW is estimated at 116.3 MW and remains fully undeveloped. The estimate of potential capacity is based on the total planned capacity of 18 SHP projects intended to enter into operation between 2029 and 2036.

Peru has an installed capacity of 503.8 MW for SHP of up to 20 MW, while potential capacity is estimated at 3,500 MW, indicating that over 14 per cent has been developed. The country's SHP capacity has increased dramatically in recent years, and at least 11 new plants have been commissioned between 2016 and 2019. There were 24 ongoing SHP projects in Peru as of 2021, with construction to be completed by 2024.

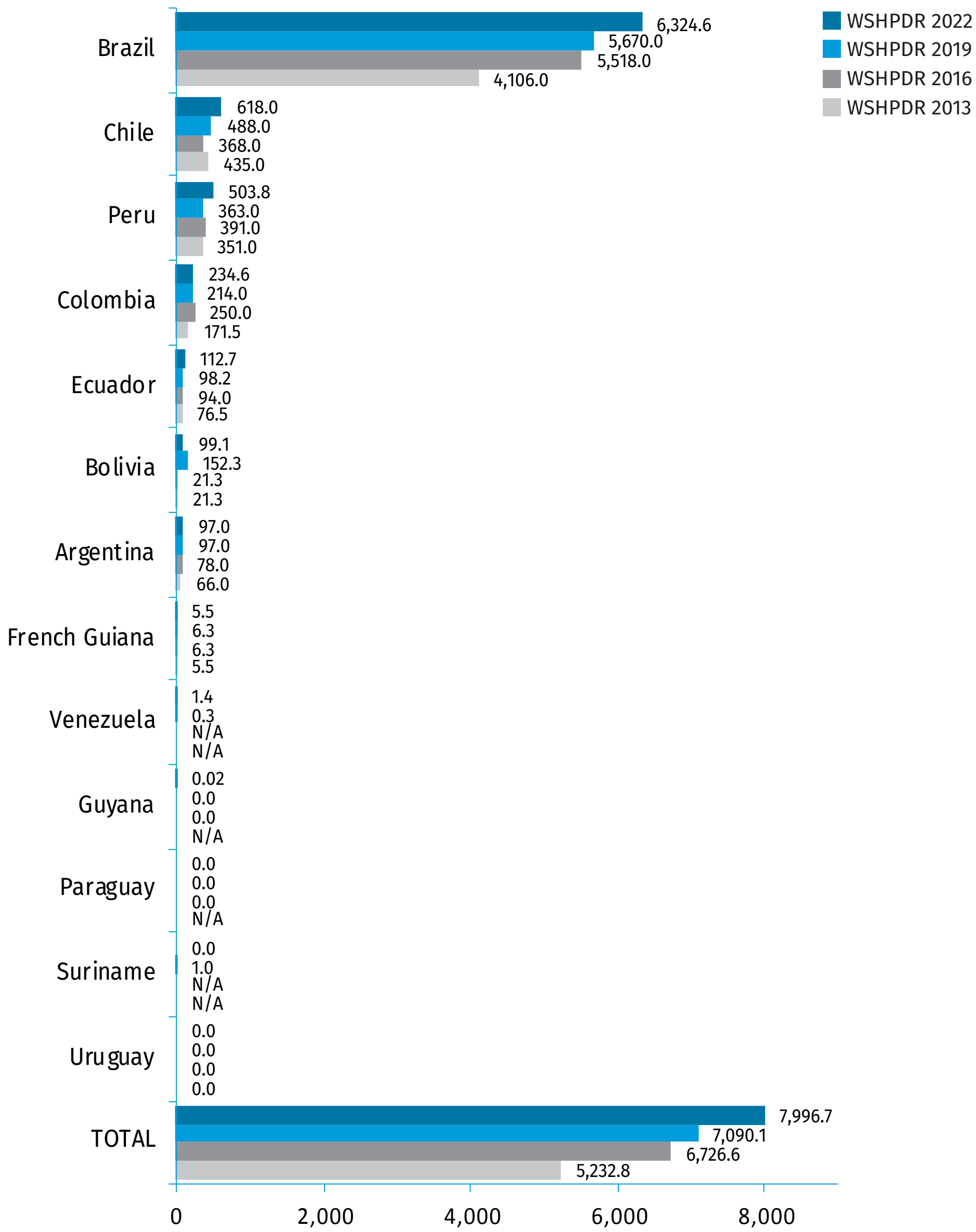
Suriname has no operational SHP capacity, although 2.7 MW of potential for SHP of up to 10 MW has been identified. Several formerly operational SHP plants exist in the country, but there are no known plans for their rehabilitation or for the construction of any new SHP plants.

Uruguay likewise has no installed SHP capacity. Potential capacity for SHP of up to 50 MW is estimated at 231.5 MW, while for SHP of up to 10 MW it is estimated at 208 MW, and remains fully undeveloped. Several studies have been carried out over the last decade assessing the technical and economic feasibility of multiple potential SHP sites, but there are no specific plans for any new SHP construction.

The installed capacity of SHP of up to 10 MW in **Venezuela** is 1.4 MW, provided by seven SHP plants, of which the most recent one was built in 1994. Potential capacity for SHP of up to 10 MW is estimated at 49.7 MW, indicating that 3 per cent has been developed. Ten potential SHP sites have been identified, but there has been little SHP development in recent years and there are no planned or ongoing SHP projects in the country.

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

Figure 3. **Change in Installed Capacity of Small Hydropower from *WSHPDR 2013* to *WSHPDR 2022* by Country in South America (MW)**



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

Note: For SHP of up to 10 MW except in the case of Brazil, Chile and Peru, where the local definition is used for the purpose of comparison with the previous editions of the *WSHPDR*.

Climate Change and Small Hydropower

The glacial stability of the mountainous regions in the western part of South America is affected by climate change. In the short term (the next 10 to 20 years), an initial increase in runoff could lead to a parallel increase in SHP plant capacity factors in the Andean region, but the loss of glacial cover risks making hydropower less viable in the long term by the end of the century. In the eastern part of South America, climate change projections indicate a decrease in rainfall and an increase in temperature during the peak rainfall season, combined with less precipitation during the dry season. The expected decreased runoff and an increase in seasonal flow variability threatens the viability of run-of-river hydropower projects.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Barriers to SHP development in **Argentina** include a lack of up-to-date studies of SHP potential, technical constraints on the addition of new capacities to the electricity grid and long-term impacts of climate change including the depletion of glaciers, which is expected to lead to reductions in runoff. At the same time, the country possessed a considerable undeveloped SHP capacity, an inventory of identified potential sites and a well-established SHP sector. Financing for future SHP projects is available through the country's RenovAr programme.

Bolivia has prioritized the development of large hydropower over SHP, and the country lacks a clear framework for the development of SHP projects and detailed data on potential sites. Low electricity prices in the country limit the attractiveness of SHP projects to private investors. Additionally, there has been a degree of resistance from local communities against hydropower projects. On the other hand, despite the lack of clear data, SHP potential in the country is believed to be considerable. Many rural communities could benefit from electrification delivered by off-grid SHP projects. Additionally, opportunities exist with regard to repair and refurbishment of existing plants.

Despite a very active SHP sector, obstacles to SHP development in **Brazil** include limited incentives for SHP relative to other RES, high construction and operating costs and strict environmental requirements fuelled in part by public scepticism about hydropower development in general. Overall, however, the outlook for the SHP sector in Brazil is positive as the country has extensive experience in SHP development and the sector is represented by an industry group of SHP developers. With a very significant SHP potential remaining untapped, particularly for SHP of up to 30 MW, the presence of incentives for SHP of below 5 MW and specific government targets for SHP expansion over the next decade can be expected to drive additional expansion of SHP capacities.

There are a number of factors complicating SHP development in **Chile**. These include a broad range of issues related to water use rights, lack of information and engagement with local communities on prospective and ongoing projects, unclear environmental standards and increasing water stress as a result of climate change. However, the country's undeveloped SHP potential remains one of the largest in the region. Chile has indicated its commitment to RES development and decarbonizing the economy, with SHP poised to play an important role in this process.

A major barrier to further SHP development in **Colombia** is the variability in generation from hydropower due to the effects of climate change, which is causing the country to reconsider its dependence on hydropower and prioritize the development of other RES. Additionally, institutional fragility and obstacles in negotiating with local communities and landowners can discourage investment in SHP, particularly in remote areas. The main enabler of SHP development in Colombia is the country's significant untapped SHP potential.

Similar to other countries in South America, the electricity sector development strategy of **Ecuador** has prioritized large hydropower plants over SHP. Additionally, despite the country's abundant undeveloped SHP potential, there is a lack of detailed data on technical and economic potential. At the same time, recent legislation on distributed generation and newly-proposed incentives for RES may provide a boost to SHP development in the country.

The main barrier to SHP development in **French Guiana** is significant seasonal variability of rainfall and runoff as a result of climate change, which poses a major challenge to stable hydropower generation in the country. Additional obstacles include administrative hurdles, high cost of electricity and difficulties with power transmission in remote parts of the country. Enablers of SHP development in the country include the planned partial closure of existing thermal power capacity, which is expected to act as a catalyst of RES development, as well as existing undeveloped SHP potential.

In **Guyana**, SHP development is hampered by a lack of detailed hydrological data, difficulties in providing grid connections and road access to project sites, and lack of local technical expertise. However, the rapid economic growth of Guyana over the last couple of decades, coupled with some recent momentum in the SHP sector including increased financing opportunities, may contribute to ongoing development of SHP in the country.

The main barrier to SHP development in **Paraguay** is the country's focus on large hydropower and the institutional structure underlying the current model of electricity generation in the country, which is heavily export-oriented. In addition, new policies have prioritized the development of RES other than hydropower. At the same time, the country has significant untapped SHP potential, and SHP could be employed to localize and increase the reliability of electricity supply in some areas suffering from high transmission losses.

Barriers to SHP development in **Peru** include the high initial cost of investment relative to thermal power, lack of human capacity for operation and maintenance of SHP plants, insufficient awareness among potential investor of the profitability of RES projects and issues with transportation infrastructure. Concerns over the potential environmental impact of SHP plants present an additional obstacle. Enablers include the country's extensive experience with hydropower and SHP in particular, abundant undeveloped SHP potential and several forms of support including long-term power purchase agreements, tax waivers and guaranteed purchase prices for electricity generated by SHP.

In **Suriname,** SHP development is hampered by high start-up costs, lack of funding and lack of local technical capacity in the SHP sector. The main potential driver of future SHP development in the country is the acute need of many rural settlements for stable electricity access.

The main barriers to SHP development in **Uruguay** are the country's focus on large hydropower, high costs of SHP projects relative to other RES, limited incentivization and socio-environmental restrictions. At the same time, abundant identified potential capacity and previous detailed studies of potential sites, in addition to a policy framework generally supportive of RES development, provide a solid base for future SHP development in the country.

In **Venezuela**, the main barrier to SHP development is the ongoing crisis in the electricity sector that has forced the Government to focus on large-scale projects. Additionally, data on potential sites as well as the state of existing plants is insufficient to promote development in the SHP sector. However, SHP projects could help promote decentralized generation and increase the stability of the electricity supply, particularly in the north-western part of the country, which is located farther away from existing hydropower plants and suffers from increased transmission losses.

REFERENCES

1. UNIDO, ICSHP (2022). *World Small Hydropower Development Report 2022*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR2022.
2. UNIDO, ICSHP (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
3. UNIDO, ICSHP (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
4. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.

Argentina

Raul Pablo Karpowicz, KWZ

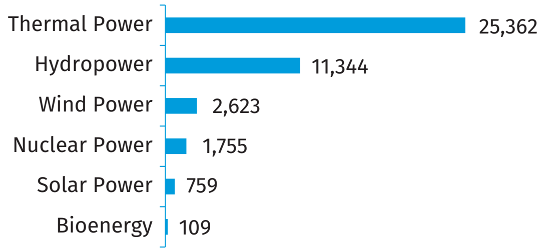
KEY FACTS

Population	45,377,000 (2020)[1]
Area	2,780,400 km^2 [2]
Topography	The terrain comprises rich plains of the Pampas in the northern half, a flat to rolling plateau of Patagonia in the south and the rugged Andes along the western border. The highest point is Aconcagua, at 6,962 metres.[3]
Climate	Argentina is located within the subtropical-temperate zone. However, its extension between approximately 22° SL and 55° SL ensures great climatic diversity The north of the country has a warm and humid subtropical climate. Central Argentina has a temperate continental climate, with very hot summers and mild winters. The South has a subarctic climate and is directly influenced by the prevailing westerly winds. As the prevailing westerly winds lose their moisture and descend into Argentina, temperatures increase while humidity decreases. In the West, the Andes Mountain Range is a great determinant of the regional climate, since the high peaks from 40° SL and towards the north, together with the remoteness of the Atlantic, determine continental characteristics. January is the warmest month, while June and July are the coldest. The average annual temperatures range from 10 °C in July to up to 25 °C in January.[3,4]
Climate Change	Historically, in Argentina temperatures have risen by 0.5 °C since the beginning of the 20th century. During the latter half of the century, warming was felt in Patagonia with both maximum and minimum temperatures increasing in the region. The number and intensity of heatwaves have increased between 1960 and 2010. Precipitation has increased since the early 20th century, notably in the subtropical zones, albeit variable year-on-year. Under the most extreme climate change scenario, Argentina could see an increase of 3.5 °C by the end of the century compared to the 2014 levels.[5]
Rain Pattern	Rainfall is variable, depending on location and elevation. The north receives rain throughout the year with the annual average of approximately 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. Towards the south, the mountain range is low and the ascent of the winds from the west produces precipitation on the Chilean side and over a narrow strip on the Argentinean side, and the winds subsequently lose their moisture by the time they reach the Patagonian plateau.[3,6]
Hydrology	The major rivers in Argentina include the Pilcomayo, Paraguay, Bermejo, Colorado, Río Negro, Salado, Uruguay and Paraná, the largest river in the country (15,000 m^3/s). 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 Mendoza in Mendoza province, the Chubut in Patagonia, the Río Grande in Jujuy and the San Francisco River in Salta. The provinces with the greatest small hydropower potential include San Juan, Mendoza, Rio Negro, Chubut and Santa Cruz.[3]

ELECTRICITY SECTOR OVERVIEW

At the end of 2020, the total installed capacity of Argentina was 41,952 MW.[7] The installed capacity of fossil fuel-powered thermal power plants (diesel or natural gas) was 25,362 MW. The installed capacity of hydropower amounted to 11,344 MW. Nuclear power accounted for 1,755 MW and wind power (2,623 MW), solar power (759 MW) and biomass (109 MW) made up the non-hydropower renewable sources (Figure 1).[7]

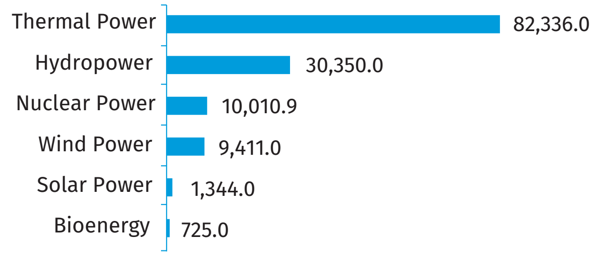
Figure 1. **Installed Electricity Capacity by Source in Argentina in 2020 (MW)**



Source: CAMMESA[7]

Total electricity generation in 2020, discounting imports, was 134,177 GWh (135,381 GWh including imports). The contribution of small hydropower SHP (below 50 MW) amounted to 1,257 GWh, whereas large hydropower contributed 29,093 GWh, totalling 30,350 GWh. Non-hydropower generation came from thermal power (82,336 GWh), nuclear power (10,011 GWh), solar power (1,344 GWh), wind power (9,411 GWh) and bioenergy (725 GWh) (Figure 2).[7]

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



Source: CAMMESA[7]

During the last 15 years the share of hydropower in the total installed capacity of Argentina has decreased, mainly because thermal power, wind power and solar photovoltaic (PV) power are less time-intensive from project conception to operation. The decreasing international equipment prices in solar PV and excellent wind capacity factors in the Patagonia as well as promotion of renewable energy have supported this tendency. Moreover, construction of large hydropower plants in Argentina is complicated due to an unstable economic situation in the country and environmental concerns. Theoretically, the country has enough water resources to generate approximately 170,000 GWh annually.[7] However, so far it barely produces 20–25 per cent of that energy volume.[8]

Transactions between the different participants in the electricity industry are carried out through the Wholesale Electricity Market (WEM) controlled by the Wholesale Electricity Market Management Company (Compañía Administradora del Mercado Mayorista Eléctrico, CAMMESA), the administrator of the electricity market. The WEM is organized as a competitive market in which generators, distributors and certain large electricity users can buy and sell electricity at prices determined by supply and demand; others are allowed to enter into long-term electricity supply contracts. The WEM consists of:

- A term market where the quantities, prices and contractual conditions are agreed on directly between sellers and buyers according to specific resolutions, such as the "Term Market for Renewable Energies" (MAT ER), established by Resolution No. 281/2017 of the former Ministry of Energy and Mining;
- A spot market, where prices are established per hour based on the economic cost of production;
- A stabilized system of spot prices through seasonal prices, established every six months and designed to mitigate the volatility of spot prices for the purchase of electricity by distributors.[9]

The electricity is transported through the SADI (Argentina Interconnected System). There are public and private companies involved in the generation, transport and distribution of energy. Pampa Energía is one of the fast-growing private companies that is heavily involved in the renewable energy arena.[10] The National Electricity Regulatory Commission (ENRE) is an independent entity within the State Secretariat for Energy and is responsible for regulating the energy industry.

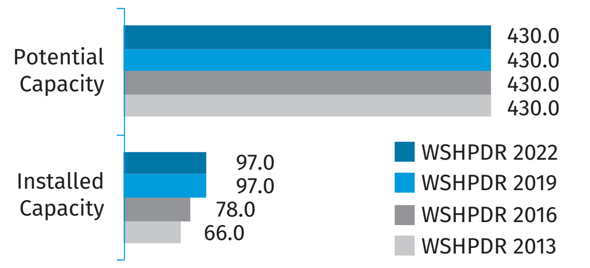
The large interconnection networks allow the transportation of energy flows at a regulated cost. However, transmission lines at medium and high voltage are not enough to satisfy new generation. This is a structural deficit to be overcome, as larger energy projects are unable to connect due to these transmission grid capacity constraints. Nonetheless, the country has had 100 per cent electrification since 2017.

Public electricity tariffs are regulated by the Government. As of March 2021, the household prices were 0.058 USD/kWh, while business prices were 0.039 USD/kWh.[11] Prices were frozen in 2019 following a period of high inflation that drastically impeded the country's economic growth and reduced consumer spending power. More recently in May 2019, the regulator announced that distribution firms Edenor and Edesur would introduce a 9 per cent tariff increase around the city of Buenos Aires to guarantee continuity in provision, with immediate effect.[12]

SMALL HYDROPOWER SECTOR OVERVIEW

In Argentina, SHP is classified as hydropower plants with an installed capacity of less than 50 MW. For the purposes of comparison with the previous editions of the *World Small Hydropower Development Report* (*WSHPDR*), the 10 MW definition will be used in this chapter. The current installed capacity of SHP plants of under 10 MW is 97 MW from 24 plants, thus there is no change from the *WSHPDR 2019* capacity levels (Figure 3, Table 1).[7] There are 43 SHP plants of a capacity of less than 50 MW, with a total of 510 MW of installed capacity.[6] There is no updated information on overall potential capacity since the previous editions of the *WSHPDR*.

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



Source: CAMMESA,[7] *WSHPDR 2013*,[13] *WSHPDR 2016*,[14] *WSHPDR 2019*[15]

Note: Data for SHP up to 10 MW.

There is a great potential for SHP in Argentina. A national inventory of SHP facilities was conducted by the former Ministry of Energy and Mining has identified 116 potential projects, at different levels of development (see Table 3).[16] 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 have been 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 remuneration for potential investors and companies interested. In addition, ensuring that all provinces of Argentina accept and implement the distributed generation law may further enhance the development of SHP in the country.

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

Name	*Location*	*Capacity (MW)*	*Operator*
CACVHI	Cuyo	9	CONSORCIO POTRERILLOS
SANDHI	Comahue	7.9	CENTRAL SALTO ANDERSEN
RESCHI	Comahue	7.2	PAH RIO ESCONDIDO-PATAG
RREYHI	Noa	7	HIDROELECTRICA REYES EJSEDSA
COROHI	Cuyo	6.64	GENERADORA ELECTRICA MENDOZ.SA
SMARHI	Cuyo	6.48	GENERADORA ELECTRICA MENDOZ.SA
LUNLHI	Cuyo	6.34	PAH LUNLUNTA - EMESA
PMORHI	Centro	6.3	EPEC GENERACION
ROMEHI	Comahue	6.2	CENTRAL JULIAN ROMERO 5 SALTOS
CIPOHI	Comahue	5.4	CENTRAL HIDRAULICA CIPOLLETTI
CESPHI	Comahue	5.2	CENTRAL HIDRAULICA CESPEDES
LMO2HI	Centro	4.5	EPEC GENERACION
CALEHI	Centro	4.4	EPEC GENERACION
GROCHI	Comahue	2	EMP DE ENERGIA DE RIO NEGRO SA
LQUIHI	Noa	2	HIDROELECTRICA RIO HONDO SA
LUJAHI	Cuyo	1.7	PAH LA LUJANITA - ENARSA
TBENHI	Cuyo	1.7	PAH DIQUE TIBURCIO BENEGAS
GUA6HI	Cuyo	1.2	PAH CAN.CQUE GUAYMALLEN SALTO6
GUA7HI	Cuyo	1.2	PAH CALBUCO SALTO7
GUA8HI	Cuyo	1.2	PAH CAN.CQUE GUAYMALLEN SALTO8

Source: CAMMESA[7]

Western areas of the country are very attractive for SHP development. Wind power is growing very fast because of the high-capacity factors in Patagonia (south of the country); however, the transmission lines capacity remains a limiting factor. Solar PV plants are being developed mainly in the north (Jujuy province). Several SHP projects are in planning at various stages (Table 2). However, the planning timelines have been drawn out over several years and the current status of these projects is difficult to determine. Table 3 presents a list of projects available for investment.

Table 2. **List of Selected Planned Small Hydropower Projects in Argentina**

Name	*Location*	*Capacity (MW)*
Corpus	Misiones, international with Paraguay	3.8
Patí o Machuca Cué	Corrientes – Santa Fe	2.9
Chapetón	Entre Ríos – Santa Fe	2.3
Garabí	Corrientes, international with Brazil	1.6
Cordón del Plata	Mendoza	1.5

Source: Hydro Review,[17] Bnamericas,[18] Water Power Magazine[19]

Table 3. **Small Hydropower Projects Available for Investment in Argentina**

Name	*Location*	*Potential capacity (MW)*
La Quebrada	Lules River, Tucumán	5.6
Luján de Cuyo	Mendoza River, Mendoza	1.1
San Martín de los Andes	Chapelco River, Neuquén	0.4
Caviahue	Agrio River, Neuquén	0.4
Andalgalá	Andalgalá River, Catamarca	0.4

Source: Ministry of Economy, Energy Secretariat[16]

RENEWABLE ENERGY POLICY

By October 2015, Law No 27.191 was enacted (regulated by the necessity and urgency Decree No. 531/16), modifying Law No 26.190 to promote the use of renewable energy sources.[20,21] Among other measures, it was established that by 31 December 2025, 20 per cent of the total energy demand in Argentina must be covered with renewable energy sources. To achieve this objective, the GUs (large users) of the WEM and CAMMESA must cover 8 per cent of their demand with renewable sources as of 31 December 2017. This percentage is to be increased every two years until reaching the aforementioned objective. The contracts entered with GUs and GUDIs (large distribution users) cannot have an average price exceeding 113 USD/MWh.

Resolution No. 281/17 of the MEyM (former Ministry of Energy and Mining) issued in 2017 regulates the Term Market of Renewable Energies (MAT ER) regime. The resolution established the conditions for GUs of the WEM (Wholesale Electricity Market) and GUDIs to follow in relation to their obligation to meet their demand through renewable sources, whether through individual contracting in the MAT ER or by self-generation. Likewise, the conditions that generation projects must meet are regulated. In particular, the RENPER (Registry of Electric Power Generation Projects from Renewable Source) was created, in which such projects must be registered.[22]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

Currently, the legal umbrella for SHP is Law No. 27.191, which modifies Law No. 26.190 to promote the use of renewable energy sources.[23] CAMMESA controls the transactions of energy based on conditions or regulations, such as the contracts awarded in the RenovAr programme and contracts in the MAT EW market. Water use rights and permits, including environmental permits, are the jurisdiction of provinces. SHP plants whose energy production is not transported by the interconnected system are regulated by the provinces in accordance with the national laws. The Regulatory National Dam Safety Argentinian Authority (ORSEP) is the national entity responsible for regulating the safety dams in the country, including those used for hydropower generation.

The Ministry of Economy Energy Secretariat has a directorate directly involved in the promotion of SHP in the country, the National Directorate for Promotion (DNPROM). The objectives of the DNPROM include:

- Surveying the facilities in operation and out of service as well as those suitable for refurbishment and of public irrigation structures that can be equipped with generating units;
- Compilation, review and proposal of reformulating the provincial legal regimes of water, environment and energy, in agreement and collaboration with governments and provincial agencies;
- Analysis of the profitability of SHP in isolated markets, development of case studies and a roadmap of projects related (or not) to the Clean Development Mechanism;
- Identification and management of public and private financing lines for the execution of the technical and economically feasible works.

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

SHP is promoted by the Government's programme RenovAr, which called for bidders interested in investing, who then receive a payback from sales of energy during a period of up to 20 years. The RenovAr programme is controlled by the Ministry of Economy Energy Secretariat 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 renewable sources and the adjustments of the referential prices. Referential prices depend on the energy source — wind power, solar PV, biomass or hydropower. The latest prices awarded during the second round were between 89 USD/MWh and 105 USD/MWh.[24] Nine projects were awarded in round 2, representing a total capacity of 21 MW (Table 4).[23]

Table 4. **Small Hydropower Plants awarded under RenovAr Round 2**

ID	*Name*	*Location*	*Potential capacity (MW)*	*Applicant*
PAH-709	P.A.H. Boca del Rio	Centro, Córdoba	0.5	EPEC
PAH-708	P.A.H. Cruz del Eje	Centro, Córdoba	0.5	EPEC
PAH-710	P.A.H. Pichanas	Centro, Córdoba	0.5	EPEC
PAH-700	P.A.H. Las Tunas	Cuyo, Mendoza	10.0	CONSTRUCCIONES ELECTROMECÁNICAS DEL OESTE S.A.
PAH-702	P.A.H. Salto 7	Cuyo, Mendoza	1.2	CONSTRUCCIONES ELECTROMECÁNICAS DEL OESTE S.A.
PAH-712	P.A.H. Lunlunta	Cuyo, Mendoza	6.3	NEXO ENERGIA S.A.
PAH-715	P.A.H. Salto 11	Cuyo, Mendoza	0.5	SKRU S.A.
PAH-714	P.A.H. Salto 40	Cuyo, Mendoza	0.5	SKRU S.A.
PAH-705	P.A.H. Salto De La Loma	Cuyo, San Juan	0.7	LATINOAMERICANA DE ENERGÍA S.A.

Source: Ministry of Economy, Energy Secretariat[23]

Additionally, renewable energy projects can benefit from various incentives, including tax benefits (early VAT refund, accelerated amortization of income tax, exemptions from import duties, etc.), and the constitution of the Fund for the Development of Energy Renewables (FODER), which is destined, among other objectives, to grant loans, capital contributions, etc. to contribute to the financing of such projects.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

As a result of climate change, the Paraguay, Uruguay and Paraná Rivers have seen an increase in their mean flows as well as the frequency of extreme discharge events.[4] The glacial stability of the Andes Mountains is also affected by climate change as glacial melt puts at risk the balance of water provision for hydropower dams. The initial increase in runoff could increase plant capacity factors but make hydropower business models less viable in the long term.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Argentina has great SHP potential. Overall, hydropower is considered as an available and economical technology for national development in the long term, which, if appropriately planned, can serve multiple purposes, including tourism, water supply, flood control, irrigation, local development, etc. However, several barriers hinder further development of the SHP technology in the country, including the following:

- Extensive studies involving multiple jurisdictions with corresponding permits and environmental concerns delaying new projects;
- Slow development of the sector in recent years;
- Electricity grid constraints limiting new capacity additions;
- Long-term detrimental effects of climate change due to the depletion of glacial water resources;
- Limited information on potential capacity and sites.

The following points summarize the main enabling factors for further SHP development in the country that have been identified:

- A decent baseline of operational SHP projects as evidence of the viability of the technology in Argentina;
- An inventory of potential sites for development is available, albeit missing capacity-specific information;
- Potential short-term increase in plant capacity due to climate change effects and glacial melt;
- Availability of financing from the national RenovAr programme.

In this context, it appears critical to create new specific legal incentives that could facilitate SHP development, considering all its benefits that other renewable energy technologies cannot offer. Public-private solutions or refurbishment of old power plants could offer key opportunities for the development of the SHP sector.

REFERENCES

1. World Bank (2020). *Population, Argentina*. Available at https://data.worldbank.org/indicator/SP.POP.TOTL?locations=AR (Accessed 26 October 2021).
2. World Bank (2021). *Argentina - Surface Area (sq. Km)*. Available at https://tradingeconomics.com/argentina/surface-area-sq-km-wb-data.html#:~:text=km (Accessed 28 October 2021).
3. United Nations Food and Agriculture Organization (FAO) (2015). *Country Profile - Argentina*. Aquastat database. Available at https://www.fao.org/3/ca0438es/CA0438ES.pdf (Accessed 28 October 2021).
4. Climate Data (n.d.) *Climate: Argentina*. Available at https://en.climate-data.org/south-america/argentina-11/ (Accessed 14 November 2021).
5. Barros, V., Boninsegna, J., Camilloni, I., Chidiak, M., Magrín, G. & Rusticucci, M. (2014). *Climate change in Argentina: trends, projections, impacts and adaptation*. Available at https://www.researchgate.net/publication/267762362_Climate_change_in_Argentina_Trends_projections_impacts_and_adaptation (Accessed 28 October 2021).
6. Bianchi, A.R. and Cravero, S.A.C (2010). *Digital Climate Atlas of the Republic of Argentina [Atlas Climático Digital De La República Argentina]*. Available at https://inta.gob.ar/sites/default/files/script-tmp-texto_atlas_climtico_digital_de_la_argentina_110610_2.pdf (Accessed 29 October 2021).
7. Wholesale Electricity Market Management Company (CAMMESA) (2020). *Annual Information: Annual evolution of installed capacity [Informe Anual: Evolución anual de la Potencia Instalada]*. Available at https://cammesaweb.cammesa.com/informe-anual/ (Accessed 29 October 2021).
8. Argentina Institute for Energy (IAE) (2015). *La política para salir de la crisis energética*. Available at https://web.iae.org.ar/ex-secretarios-consensos-energeticos-2015-la-politica-para-salir-de-la-crisis-energetica-rustica/#.YXwVDJ7M-Lb0 (Accessed 29 October 2021).
9. Ministry of Economy, Energy Secretariat (2017). *Resolución E 281 / 2017*. Available at https://www.argentina.gob.ar/normativa/nacional/resoluci%C3%B3n-281-2017-278429 (Accessed 31 October 2021).
10. Pampa Energia (n.d.). *The Electricity Sector of Argentina [El Sector Eléctrico de Argentina]*. Available at https://ri.pampaenergia.com/nuestros-activos/electricidad/el-sector-electrico-de-argentina/ (Accessed 31 October 2021).
11. Global Petrol Prices (2021). *Argentina electricity prices*. Available at https://www.globalpetrolprices.com/Argentina/electricity_prices/#:~:text=Argentina%2C%20March%202021%3A%20The%20price,of%20power%2C%20distribution%20and%20taxes (Accessed 30 October 2021).
12. Reuters (2021). *Argentina power firms hike prices after freeze since 2019*. Available at https://www.reuters.com/business/energy/argentina-power-firms-hike-prices-after-freeze-since-2019-2021-05-01/ (Accessed 30 October 2021).
13. UNIDO, ICSHP (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
14. UNIDO, ICSHP (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
15. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
16. Ministry of Economy, Energy Secretariat (2021). *Inventory of documents and plans corresponding to hydropower projects [Inventario de documentos y planos correspondientes a proyectos hidroeléctricos]*. Available at

http://datos.minem.gob.ar/dataset/b33aca04-81d8-44ef-8842-162aa69330ca/archivo/ddcd82c5-318e-4bf2-8a2c-c637048d4b03 (Accessed 31 October 2021).

17. Hydro Review (2013). *Eletrobras proactive in engaging public about Garabi, Panambi hydroelectric plants*. Available at https://www.hydroreview.com/world-regions/eletrobras-practive-in-engaging-public-about-garabi-panambi-hydroelectric-plants/#gref (Accessed 32 October 2021).
18. Bnamericas (2016). *Argentina's Mendoza province aims to jump-start hydroelectric projects*. Available at https://www.bnamericas.com/en/news/argentinas-mendoza-province-aims-to-jump-start-hydroelectric-projects (Accessed 31 October 2021).
19. Water Power Magazine (2006). *Argentina*. Available at https://www.waterpowermagazine.com/news/newsargentina/ (Accessed 31 October 2021).
20. National Congress of Argentina (2015). *Law 27.191*. Available at http://www.senado.gov.ar/parlamentario/comisiones/verExp/78.14/S/P
21. National Congress of Argentina (2006). *Law 26.190*. Available at http://servicios.infoleg.gob.ar/infolegInternet/anexos/120000-124999/123565/texact.htm (Accessed 8 November 2021).
22. Law Portal (2021). *Modification of the Regime of the Term Market of Electric Energy from Renewable Source (MATER).* Available at https://lawportal.com/silva-ortiz-alfonso-pavic-louge/legal-insights/modification-of-the-regime-of-the-term-market-of-electric-energy-from-renewable-source-mater/ (Accessed 31 October 2021).
23. Official Gazette Argentina (2015). *Act 27191: Legal Regulations on National Promotion for the Use of Sources of Renewable Energy – Electric Power Generation – Amendment*. Available at http://www.energia.gob.ar/contenidos/archivos/Reorganizacion/renovables/legislacion/ARGENTINA_-_Renewable_Energy_Law_Act_27191_%28English_version%29.pdf (Accessed 31 October 2021).
24. Ministry of Economy, Energy Secretariat (n.d.) *Prices awarded under the RenovAr Programme. Rounds 1, 1.5 and 2 [Precios adjudicados del Programa RenovAr. Rondas 1, 1.5 y 2]*. Available at https://www.minem.gob.ar/www/833/25871/precios-adjudicados-del-programa-renovar (Accessed 31 October 2021).

Bolivia (Plurinational State of)

Cleber Romao Grisi, WHITEnergy Bolivia

KEY FACTS

Population	11,673,029 (est. 2020)[1]
Area	1,098,581 km^2 [2]
Topography	Bolivia is a landlocked country with geographic zones featuring great variations in altitude.[1,3,4] The Andean zone lies in the west of the country and covers approximately 28 per cent of the national territory. It is a mountainous zone formed by the Occidental, the Oriental, the Royal, the Cordillera Central and the Altiplano. The highest point is the Sahama peak at 6,542 metres; the average altitude in the Andean region is between 3,750 and 4,000 metres.[1,3,4] The Sub-Andean zone, commonly known as the Yungas and the Valles, consists of 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. This zone 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.[1,3,4]
Climate	The Andean zone has a desert polar climate, with strong, cold winds and high solar radiation; temperatures range between a minimum of below 0 °C and a maximum of 20 °C. The Sub-Andean zone features a very humid and rainy climate, with the average temperature ranging between 15 °C and 25 °C. Finally, the average temperature in the Eastern Plains is approximately 30 °C.[1,3]
Climate Change	Since the year 2000, the country's average temperature has increased by 0.1 °C. It is expected that the average temperature will rise by 3.6–5.1 °C by the year 2100. The major effects of the rising average temperatures in Bolivia include the disappearance of glaciers on mountaintops (for example, the Chacaltaya Peak), a decrease in rainfall, a reduction of average humidity, an increase in the duration of periodic droughts, changes in the rainfall pattern and the increasing severity of flood events.[5,6,7]
Rain pattern	Bolivia has a tropical climate with average precipitation of 640 mm per year. The rainy season lasts from mid-October to March.[8,9] 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.[3,9] In the Andean zone, particularly on the Altiplano, it rains much less. Precipitation can be as low as 200 mm per year, except in the area surrounding the Titicaca Lake basin where precipitation can reach up to 1,000 mm per year.[3,9]
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 Amazon basin, which runs from the east to the west, composed 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 cross the often-flooded northern savannah and tropical forests, all converging in the north-east to form the Madera River flowing into Brazil. 2) The Central or Lake basin, formed by 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 the La Plata River basin is composed mainly of the Paraguay, Pilcomayo and Bermejo Rivers, which cross the Chaco region to the south-east as they leave Bolivia to form the border between Paraguay and Argentina.[3,4]

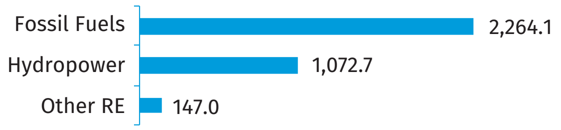
ELECTRICITY SECTOR OVERVIEW

The electricity sector of Bolivia includes the national grid, known as the National Interconnected System (SIN), several isolated networks, the wholesale market, the end consumers and the electricity authorities.[10,11]

In 2019, the total installed capacity in Bolivia was 3,483.8 MW and the total electricity generation amounted to 10,699.4 GWh, of which 89 per cent was supplied to the SIN and 11 per cent to the isolated networks.[10,12,13,14] The SIN covers the entire country except for the territory of Pando in the north.[10] In 2019, the total installed capacity of the SIN stood at 3,150.1 MW and electricity generation totalled 9,530.8 GWh. The maximum registered power demand of the end consumers amounted to 1,512.3 MW and the total electricity demand reached 9,242.2 GWh. The energy demand grew by 22 per cent relative to 2016 and by 3 per cent relative to 2018. There were 5,860.5 km of transmission lines, including 3,754.1 km at 230 kV, 1,892.2 km at 115 kV and 214.2 km at 69 kV.[10]

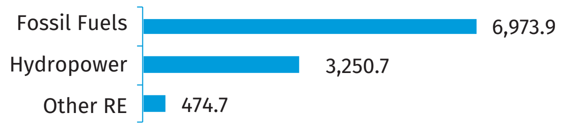
The major share of electricity in Bolivia in 2019 was produced by non-renewable thermal sources, mainly natural gas combustion and some diesel turbines, with an installed capacity of 2,264.1 MW (65 per cent of the total) and an annual generation of 6,973.9 GWh (65 per cent of the total), followed by hydropower with an installed capacity of 1,072.7 MW (31 per cent) and an annual generation of 3,250.7 GWh (30 per cent) and other renewable energy sources, including wind power, biomass and solar power, in total representing 147 MW of installed capacity (4 per cent) and a total annual generation of 474.7 GWh (4 per cent).[10] Figures 1 and 2 show the 2019 installed capacity and electricity generation, respectively, in Bolivia by source.

Figure 1. **Installed Electricity Capacity by Source in Bolivia in 2019 (MW)**



Source: CNDC,[10] AE[14]

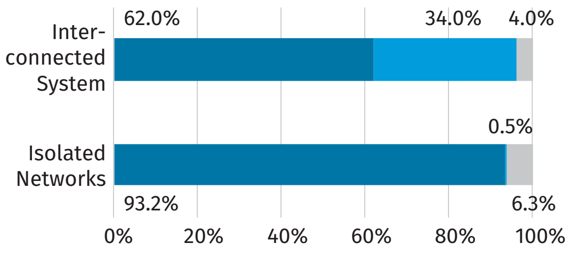
Figure 2. **Annual Electricity Generation by Source in Bolivia in 2019 (GWh)**



Source: CNDC,[10] AE[14]

In 2019, there were a total of 25 registered isolated networks in Bolivia. This represents a decrease from the number cited in the *World Small Hydropower Development Report (WSHPDR) 2019* (38 networks), which is due to the merging of some of the previously isolated networks with each other or with the national grid. Registered isolated networks use a combination of hydropower, solar power, biomass and thermal power (gas and diesel) as energy sources (Figure 3). These networks produced a total of 702.67 GWh of electricity in 2019.[14] Apart from the registered isolated networks, there are also non-registered isolated networks in many parts of the country. There is a lack of up-to-date and accurate data related to these non-registered networks; however, their combined installed capacity is estimated at 27.5 MW.[12,13,15]

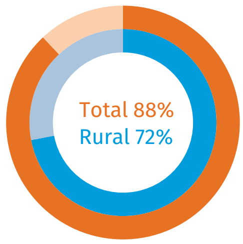
Figure 3. **Share of Installed Capacity of Electricity Networks by Energy Source in Bolivia in 2019 (%)**



Source: CNDC,[10] AE[14]

In 2019, the estimated rate of access of the population to electricity in Bolivia was 88 per cent, with urban coverage at 99 per cent and rural at 72 per cent (Figure 4).

Figure 4. **Electrification Rate in Bolivia in 2019 (%)**



Source: Ministry of Hydrocarbons and Energy[16]

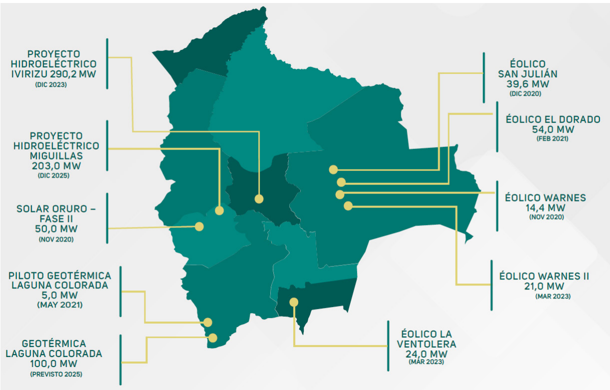
The government authorities and institutions that regulate the Bolivian electricity sector are the Ministry of Hydrocarbons and Energy, through its two vice ministries — Vice Ministry of Electricity and Alternative Energies and Vice Ministry of Energy High Technologies; the regulation and control authority, the Electricity and Nuclear Technology Supervision Authority (AE); the interconnected system administration, control and operation entity, the National Committee for Cargo Dispatch (CNDC); and the state-owned National Electricity Company (ENDE).[10,11,16]

Both public and private companies participate in electricity generation, transmission and distribution in Bolivia. The largest stakeholder is the state-owned corporation ENDE, which owns most of the generation facilities, transmission and distribution utilities across the country. In addition, ENDE is responsible for planning the growth of the electricity market and for the development of energy projects.[10,11,14,16]

In 2014, the Government issued a plan for the expansion of the electricity sector, which estimated that by 2022 electricity demand would reach 14,336 GWh/year, requiring a total installed capacity of 2,297 MW.[17] Approximately 53 per cent of this future demand was intended to be fulfilled by hydropower.[17] The current installed capacity of Bolivia has, thus, already surpassed the goal established in 2014 by a wide margin; however, demand and generation both remain below the established target.

Following the mandate of the country's constitution and electricity expansion plan, the Government of Bolivia has been developing the electricity sector by increasing the installed capacity, merging isolated networks with the national grid and expanding the transmission and distribution lines to increase access to electricity.[10,11,14,16] From 2014 to 2019, the installed capacity of the national grid increased from 1,695.8 MW to 3,150.1 MW, indicating a growth of 86 per cent. However, electricity generation during the same period increased by only 22 per cent, from 7,836.5 GWh in 2014 to 9,530.8 GWh in 2019.[10] Between 2014 and 2019, the following generation projects were completed: Misicuni hydropower plant (120 MW), San José hydropower plant I (55 MW) and II (69 MW), Oruro Phase 1 solar power plant (50 MW), Uyuni solar power plant (60.1 MW), Yunchará solar power plant (5 MW), Termoeléctrica del Sur thermal combined cycle plant (263.2 MW), Warnes thermal combined cycle plant (269.2 MW), Entre Ríos thermal combined cycle plant (272.8 MW), expansion of the Unagro biomass plant (14.2 MW) and the Aguaí biomass plant (6 MW). Additionally, a number of merged isolated networks supplied by diesel generators contributed to the SIN capacity expansion with a total of 5.4 MW.[16] As of early 2021, there were 10 renewable energy projects under construction as part of the SIN expansion, of which 493 MW belonged to hydropower, 50 MW to solar power, 105 MW to geothermal power and 153 MW to wind power sources distributed throughout the country (Figure 5).[16]

Figure 5. **Energy Projects under Construction in Bolivia**

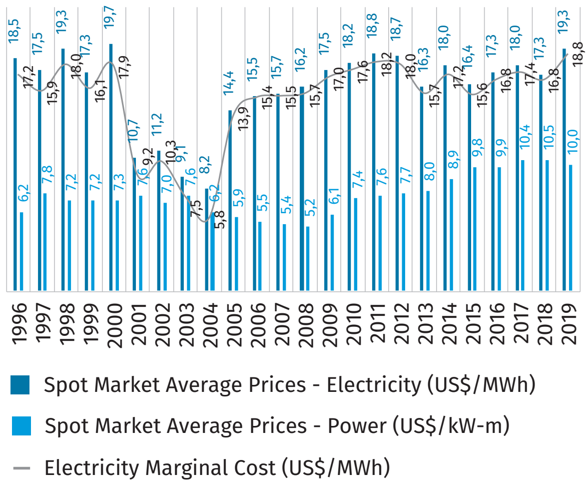


Source: Ministry of Hydrocarbons and Energy[16]

Despite fossil fuels being the predominant energy source, the electricity tariffs in Bolivia are among 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 belongs to the non-regulated group. Those in the non-regulated group can participate in the spot market as well as make power purchase agreements (PPA), which are to be first 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. The electricity transactions are held in the wholesale spot market administered by the CNDC, which is also responsible for the operation, safety and optimization of the national grid.[10,11,14]

For the commercial transactions in the SIN, on the spot market, the electricity sales are paid by the sum of two figures: the electricity produced and the power availability. The electricity sales price is a function of the generation marginal cost. This represents the electricity 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 electricity 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 electricity demand.[10] In 2019, the average electricity marginal cost in the spot market was 18.84 USD/MWh and the corresponding average electricity sales price was 19.33 USD/MWh. The average power availability price per month was 10.0 USD/kW. Figure 6 shows the variation of electricity and power availability prices in the spot market since 1996.[10]

Figure 6. **Spot Market Marginal Cost and Sales Prices in Bolivia in 1996–2019**



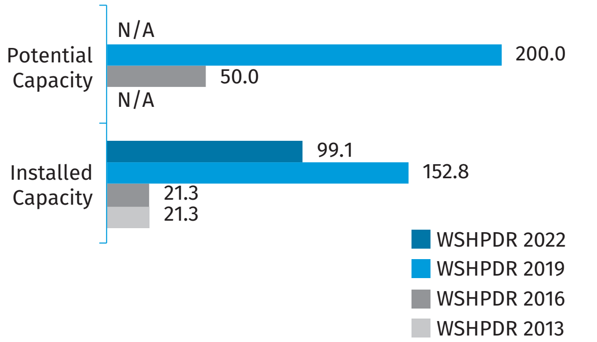
Source: CNDC[10]

SMALL HYDROPOWER SECTOR OVERVIEW AND POTENTIAL

The definition of small hydropower (SHP) in Bolivia is up to 5 MW; however, for the purposes of this Report, the standard definition of up to 10 MW will be used. Approximately 9 per cent of the electricity produced to supply the SIN comes from SHP plants (< 10 MW). These facilities belong to both private and public (ENDE) companies.[10]

In 2019, the installed capacity of SHP in Bolivia was 99.1 MW. Of this total, 12 plants with a total of 25 operational units and a combined capacity of 69.2 MW were connected to the national grid and one registered SHP plant of 1.2 MW capacity (Yocalla) was operating on an isolated network (Table 1).[14] The estimated electricity generation of the SHP plants connected to the national grid was 780.3 GWh in 2019.[10] Compared to the *WSHPDR 2019*, the installed capacity reported for SHP plants in Bolivia is lower by 53.7 MW (approximately 35 per cent) due to an earlier inclusion of hydropower plants with an installed capacity of below 30 MW and above the applicable SHP definition of up to 10 MW; which has been corrected for the current report. There is no reliable estimate of potential capacity for SHP as no specific studies related to SHP potential up to 10 MW are available; however, an overall potential capacity of approximately 200 MW for hydropower projects below 30 MW is estimated, which includes all currently installed hydropower plants of below 30 MW capacity (Figure 7).

Figure 7. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in Bolivia (MW)**



Source: *WSHPDR 2013*,[18] *WSHPDR 2016*,[19] *WSHPDR 2019*,[20] CNDC,[10] Ministry of Hydrocarbons and Energy[17]

Note: Data for SHP up to 10 MW.

Table 1. **List of Registered SHP Plants in Bolivia**

Name	*Location*	*Capacity (MW)*	*Turbine type*	*Type of plant*	*Operator*
Tiquimani	La Paz	9.7	Pelton	Run-of-river	COBBE (Private)
San Jacinto	Tarija	7.6	Pelton	Run-of-river	ENDE (Government)
Kanata	Cochabamba	7.5	Pelton	Run-of-river	SYNERGIA (Private)
Santa Rosa BC	La Paz	6.9	Francis	Run-of-river	COBBE (Private)
Botijlaca	La Paz	6.8	Pelton	Run-of-river	COBBE (Private)
Angostura	La Paz	6.2	Pelton	Run-of-river	COBBE (Private)
Choquetanga	La Paz	6.2	Pelton	Run-of-river	COBBE (Private)
Carabuco	La Paz	6.1	Pelton	Run-of-river	COBBE (Private)
Landara	Potosí	5.2	Pelton	Run-of-river	ENDE (Government)
Miguillas	La Paz	2.6	Pelton	Run-of-river	COBBE (Private)
Punutuma	Potosí	2.4	Pelton	Run-of-river	ENDE (Government)
Quehata	Oruro	2.0	Pelton	Run-of-river	ENDE (Government)
Yocalla*	Potosí	1.2	Pelton	Run-of-river	Sinchi Wayra S.A. (Private)

Source: CNDC,[10] AE[14]

Note: Yocalla SHP plant located on isolated network; data on turbine type and plant type unconfirmed.

In addition to the officially registered SHP plants, there are SHP plants providing energy to non-registered isolated networks such as small villages or industrial sites (for example, mines). Some of these plants were constructed during the development of the mining industry back in the 19th century and many others were installed within the past 40 years to meet the demand of local communities. As of 2019, there were 68 identified SHP plants on non-registered isolated networks throughout the country with an estimated total installed capacity of 28.7 MW; however, precise data on these plants is difficult to provide.[12,13,15] Most of the identified power plants are out of service or in poor condition and could be eligible for refurbishment.

Bolivia has the potential to develop 39.9 GW of hydropower capacity. The most suitable region is the Amazon 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.[10,17,21,22] SHP potential in Bolivia has been estimated for projects of up to 30 MW capacity, as part of the Government's strategic plan for the development of alternative energy sources presented in 2014. The strategic plan includes the development of micro- (<500 kW), small- (500 kW–5 MW) and medium-scale (5–30 MW) hydropower projects.[23] The plan provides for approximately 30 MW of total hydropower capacity for grid connection and another 20 MW for isolated networks to be funded through both public and private investment.[23] Identification of potential sites to fulfil these targets is required.

As of 2019, construction of the El Cóndor SHP plant is in progress. This project has an estimated capacity of 1.47 MW and an average targeted annual generation of 9.85 GWh (Table 2). The project is funded by the Government and implemented by the state-owned company ENDE Valle Hermoso. The construction works started in 2019.[24]

Table 2. **Planned SHP Project in Bolivia**

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Turbine type*	*Plant type*	*Developer*	*Planned launch year*	*Development stage*
El Cóndor	Potosí	1.47	56.58	Pelton	Reservoir	Ende Valle Hermoso	N/A	Construction

Source: ENDE Valle Hermoso[24]

RENEWABLE ENERGY POLICY

The Government has set the goal to change the country's energy mix, as of today dominated by gas units, to renewable energy sources, principally hydropower. An important reason to encourage hydropower projects is the country's enormous hydropower potential. The shift to renewable energy will also reduce natural gas use in local energy production and allow more natural gas to be instead exported to Brazil and Argentina. The export price for Bolivian gas is about seven times higher than the price established for the local market, which has been subsidized for electricity production.[10,11,17]

In 2014, the Government published the new Investment Promotion Law as well as Supreme Decree No. 2048 for remuneration of renewable energy projects and the promotion of investments in the electricity sector, in particular, hydropower, wind power, geothermal and solar power projects.[25] Therefore, today the political scene in Bolivia is becoming more suitable and attractive for both foreign and local investments in the electricity sector.[23]

Renewable energy projects, including run-of-river hydropower plants, will not be remunerated according to the actual electricity tariff system, which considers a combined payment for electricity produced and the capacity of available power. These projects will be paid for by energy production as stated in Supreme Decree No. 2048 of 2014.[25]

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 electricity price through a purchase agreement according to the requirements of ENDE, the interests of the investor and the authorizations of AE. Some benefits offered to SHP projects may include:

- Exemption from 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 ensuring generation costs to be covered and an acceptable investment return rate;
- Stable tributary conditions for 10 years;
- Possibility to defer the aggregated value tax payment for five years from the beginning of the commercial operation date; and
- Some other benefits, including the exemption from paying the transmission and the grid administrator (CNDC) fees.[23]

The Government is also working on additional structures and rules to finance SHP and other renewable energy developments, such as by assigning incentives to local (department level) authorities for projects with an installed capacity of up to 2 MW and to municipalities or to indigenous authorities for projects with an installed capacity of up to 1 MW.[23]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

According to the studies performed since 2000, climate change in Bolivia is affected by El Niño and La Niña phenomena and CO_2 emissions, and has caused an increase in the average temperature of 0.1 °C, a decrease in rainfall and a reduction of average humidity.[6,7,25]

One of the major impacts of the climate crisis in Bolivia, with direct relevance to hydropower, is the retreat of glaciers. Over the past 40 years, more than 50 per cent of the country's glaciers have disappeared. This may result in a decrease in glacial meltwater feeding into streams and aquifers, particularly in the Andean region, implying that streams will depend more on rainfall. Rainfall has a linear relationship with stream flows, thus, the variation in rainfall will have the same effects in river streams.[5,6,7] As rainfall has also been decreasing and is expected to decrease further, studies predict that hydropower generation may reduce by 18–20 per cent by the year 2100.[7]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

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

The main challenges for SHP development in Bolivia are, but not limited to:

- Government priority and policies are to develop large hydropower to export electricity to neighbouring countries;
- Renewable energy development framework, rules and conditions have not been established yet;
- The low electricity prices are not very attractive for private investments;
- Poor quality of hydrological, climate and other statistical data required for hydropower studies, especially for rural areas;
- Complications associated with the establishment of a private company or development of a private hydropower project in terms of prices, competition and

public acceptance;
- Social situation in Bolivia, including roadblocks and protests, can interfere with project development, construction and further operations;
- Projects can be cancelled due to social resistance;
- Bureaucratic procedures, authorizations and paperwork to comply with the requirements often take longer than expected.

Some enabling factors for SHP development in Bolivia include:
- A hydrological and topographic environment favourable to hydropower development, with many rivers and streams offering more than 39.9 GW of total hydropower potential;
- A large number of small communities and electricity networks isolated from the national grid and in need of additional capacities; including multipurpose projects that provide a combination of irrigation, water supply and power production.
- Many existing SHP facilities are in need of refurbishment

REFERENCES

1. United Nations (2019). *World Population Prospects 2019.* Available at https://population.un.org/wpp/Download/Standard/Population/ (Accessed 23 March 2021).
2. World Atlas (n.d.). *Bolivia Geography.* Available at https://www.worldatlas.com/maps/bolivia (Accessed 21 January 2021).
3. National Institute of Statistics (INE) (n.d.). *Geographical Aspects*. Available at https://www.ine.gob.bo/index.php/bolivia/aspectos-geograficos [in Spanish] (Accessed 12 February 2021).
4. Nations Encyclopedia (n.d.). *Bolivia Topography.* Available at https://www.nationsencyclopedia.com/Americas/Bolivia-TOPOGRAPHY.html (Accessed 25 January 2021).
5. Kaenzig, R. & Hoffmann, D. (2020). *Bolivian Andes: Interplay between glacier melting and outmigration.* Available at https://cambioclimatico-bolivia.org/archivos/20200603025549_0.pdf (Accessed 27 January 2021).
6. Oxfam International (n.d.). *Bolivia: Climate change, poverty, and adaptation*. Available at https://www-cdn.oxfam.org/s3fs-public/file_attachments/bolivia-cambio-climatico-adaptacion-sp-0911_3.pdf (Accessed 25 January 2021).
7. Andersen, L. & Jemio, L. C. (2015). *La dinámica del cambio climático en Bolivia* (Vol. 1). Institute for Advanced Development Studies.
8. National Meteorology and Hydrology Service of Bolivia (SENAMHI) (n.d.). Official website. Available at http://www.senamhi.gob.bo [in Spanish] (Accessed 8 February 2021).
9. AgroBolivia (n.d.). *Climate change in Bolivia.* Available at https://agrobolivia.files.wordpress.com/2011/03/docppver3.pdf (Accessed 12 February 2021).
10. National Committee for Cargo Dispatch (CNDC) (2019). *Annual Memorandum 2019.* Available at https://www.cndc.bo/home/media/memyres_2019.pdf [in Spanish] (Accessed 25 January 2021).
11. National Electricity Company (ENDE) (2018). *Annual Memorandum 2018.* Available at http://www.ende.bo/memorias [in Spanish] (Accessed 5 January 2021).
12. Romao, C. (2017). *Inventario de micro, mini y pequeñas centrales en Bolivia*. SOLYDES Foundation.
13. Orellana, R. & Bellot, N. (2011). *Sistemas Eléctricos Aislados y Consumo de Diesel en Bolivia*. Available at http://idbdocs.iadb.org/WSDocs/getdocument.aspx?DocNum=37860239 [in Spanish] (Accessed 18 February 2021).
14. Electricity and Nuclear Technology Supervision Authority (AE) (2020). *Statistical Yearbook 2019.* Available at https://www.aetn.gob.bo/web/main?mid=1&cid=82 [in Spanish] (Accessed 5 January 2021).
15. Monrroy Cuellar, J.L., & Montaño Gonzales, E. (2015) *Hidrogeneración en pequeña escala, una experiencia local, programa energético*. Universidad Mayor de San Andrés, Instituto de Hidráulica e Hidrología. Available at http://www.energetica.org.bo/energetica/publicacionesd.asp?d=298 [in Spanish] (Accessed 25 January 2021).
16. Ministry of Hydrocarbons and Energy (2019). *Memoria Institucional 2019*. La Paz.
17. Ministry of Hydrocarbons and Energy (2014). *Plan Óptimo de Expansión Del Sistema Interconectado Nacional del Estado Plurinacional de Bolivia 2012-2022.*
18. UNIDO, ICSHP (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
19. UNIDO, ICSHP (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
20. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
21. National Committee for Cargo Dispatch (CNDC) (2014). *Annual Memorandum 2014.* Available at https://observatorioccdbolivia.files.wordpress.com/2015/08/memoria.pdf [in Spanish] (Accessed 24 April 2021).
22. Energía Bolivia (n.d.). *Potential and exploitation of hydropower in Bolivia.* Available at 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 [in Spanish] (Accessed 12 February 2021).
23. Ministry of Hydrocarbons and Energy (2014). *Presentación: Introducción a las energías alternativas.* Seminario de Energías Renovables.
24. Ende Valle Hermoso (n.d.). *El Condor Hydroelectrical Project.* Available at https://www.evh.bo/index.php/proyectos-de-generacion/proyectos-hidroelectricos/pch/el-condor [in Spanish] (Accessed 24 March 2021).
25. Supreme Decree No. 2048 of 02 July 2014. Available at https://www.lexivox.org/norms/BO-DS-N2048.html. [in Spanish] (Accessed 1 March 2021).

Brazil

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

KEY FACTS

Population	211,755,692 (est. 2020) [1]
Area	8,510,346 km^2 [2]
Topography	The topography of Brazil is complex and includes a diversity of landscapes, but flat areas predominate. In the north lie the Amazon lowlands, which form 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 2,995.3 metres, is located. The Brazilian Highlands cover more than half of the national landmass including 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.[3,4]
Climate	The climate is tropical in the central part of Brazil, 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, the average temperature varies between 11 °C and 18 °C.[5,6]
Climate Change	Climate projections point to an increase in temperatures by 1 °C and 2.2 °C across Brazil by 2060, with the Amazon region experiencing increases of between 2 °C and 3 °C by 2050 and of as much as 5.3 °C by 2085, according to some estimates. The Amazon River delta is expected to experience a rise in sea levels of between 0.2 metres and 2 metres by 2100. Additional expected impacts of climate change in the Amazon region include the increased length of the dry season and heat waves as well as a decrease in precipitation.[7]
Rain Pattern	In the north of the country, specifically the Amazon region, the average annual precipitation varies from 1,700 mm to more than 3,000 mm in some locations. The north-eastern region experiences annual precipitation of between 300 mm and 2,000 mm. In the mid-west, precipitation is well spread and varies from 800 mm to 2,000 mm per year. In the south-east, rainfall ranges between annual averages of 800 mm in the northern part of the state of Minas Gerais and 2,500 mm on the coast of São Paulo. In the south, the precipitation varies from 1,300 mm per year to 2,100 mm per year.[8]
Hydrology	Administratively, the territory of Brazil is divided into 12 river basin districts, each containing one or more river basins. The Amazon River basin district comprises 80 per cent of all surface waters of the country.[9] The major rivers of this basin include the Amazon, Negro, Solimões, Madeira, Trombetas, Purus, Tapajós, Branco, Javari, Juruá, Xingu, Japurá and Iça. The Amazon River is the largest river in the world by volume and accounts for 20 per cent of all the fresh water flowing into the world's oceans. The Amazon River basin, is the largest in the world with an area of approximately 6,900,000 km^2, of which 3,800,000 km^2 are located on the territory of Brazil.[10]

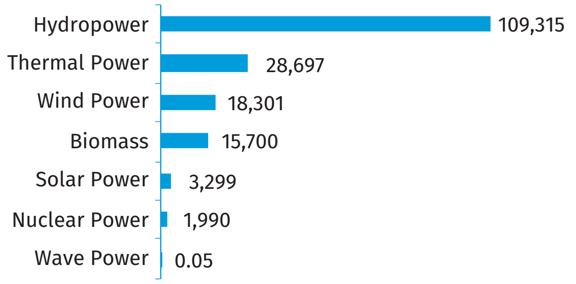
ELECTRICITY SECTOR OVERVIEW

The total installed capacity in Brazil as of April 2021 was 177.3 GW, with hydropower accounting for 62 per cent of the total, conventional thermal power 16 per cent, wind power 10 per cent, biomass 9 per cent, solar power 2 per cent and nuclear power 1 per cent (Figure 1).[11]

In 2019, the electricity sector of Brazil generated a total of 626.3 TWh of electricity.[12] Hydropower contributed 64 per cent, conventional thermal power 13 per cent, wind power 9 per cent, biomass 8 per cent, nuclear power 3 per cent, solar power 1 per cent and other sources 2 per cent (Figure 2).[12]

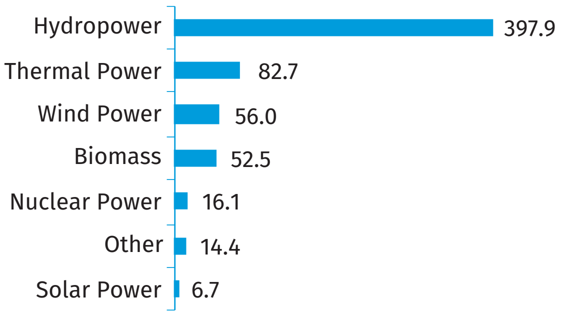
According to The World Bank, Brazil reached 100 per cent access to electricity both in urban and rural areas by 2017.[13] However, in some remote regions far from transmission lines and urban areas, access to electricity remains precarious due to dependence on diesel generators and the complicated logistics of supplying the generators with fuel. The total electricity consumption in 2019 was 545.6 TWh (1 per cent more than in 2018). Of this, 36 per cent was consumed by the industrial sector, followed by the residential (26 per cent) and commercial (17 per cent) sectors. The other sectors represented less than 10 per cent each of the total consumption (Figure 3).[12]

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



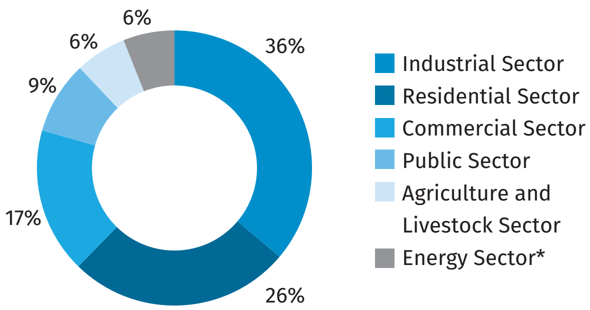
Source: ANEEL[11]

Figure 2. **Annual Electricity Generation by Source in Brazil in 2019 (TWh)**



Source: EPE[12]

Figure 3. **Electricity Consumption by Sector in Brazil in 2019 (%)**



Source: EPE[12]

Note: *Including own use.

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, 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 energy capacity of Brazil. Additionally, because of the hydrological complementarity of the Brazilian regions, hydropower projects are well-suited for an interconnected energy system. There are currently 1,377 hydropower plants in Brazil, out of a total of 9,461 power plants of all types (Table 1).[11]

Table 1. **Power Plants in Brazil – May 2021**

Type	*Number*	*Installed capacity (MW)*
Hydropower > 30 MW	219	102,990.4
Hydropower 5–30 MW	425	5,506.4
Hydropower < 5 MW	723	818.2
Thermal power	3,087	44,397.2
Wind power	718	18,300.9
Nuclear power	2	1,990.0
Solar power	4,277	3,298.9
Wave power	1	0.05
Total	**9,452**	**177,302.1**

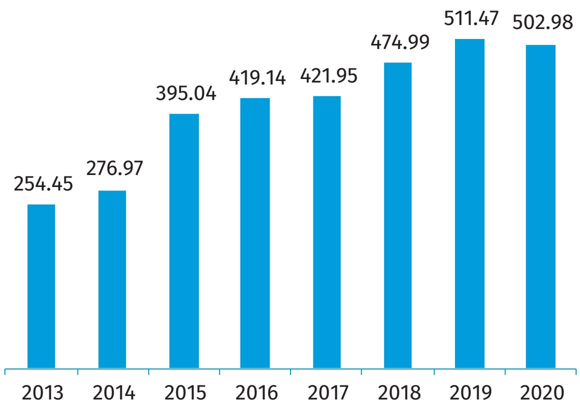
Source: ANEEL11

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.[14] However, due to the lack of investment and the 2000 drought, which culminated in a severe crisis for 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 possible and laid down the foundation for the participation of public and private actors.[14] The energy market was standardized and adopted a hybrid model 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.[15]

The Brazilian electricity sector 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 analyzing 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), which is also associated with the MME and whose role is to perform the necessary studies for planning the expansion of the electricity system. Another agent is the Chamber of Electric Energy Commercialization (Câmara de Comercialização de Energia Elétrica, CCEE), which handles negotiations on energy in the free market.[16]

Consumer tariffs are regulated by ANEEL, while 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 tariff applied in Brazil in 2020, the price decreased by approximately 1.6 per cent compared to 2019 and reached 0.503 BRL/kWh (0.0975 USD/kWh, based on the annual average dollar exchange rate) (Figure 4).[17]

Figure 4. **Average Annual Electricity Tariff in Brazil (BRL/MWh)**

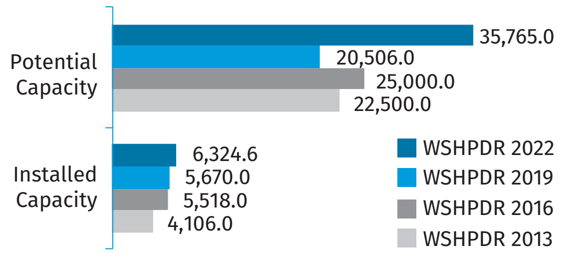


Source: ANEEL[17]

SMALL HYDROPOWER SECTOR OVERVIEW

As of May 2021, there were 1,148 small hydropower (SHP) plants up to 30 MW in operation in Brazil with a total installed capacity of 6,324.6 MW. Of these, the total installed capacity of plants up to 10 MW was 1,608.2 MW.[11] The inventoried potential of SHP in Brazil is 15,765 MW from 1,752 sites, while recent studies point to another 20,000 MW of non-detailed potential for SHP.[18] The total inventoried potential (including operational plants as well as ongoing and planned projects) for plants up to 10 MW is 3,737.8 MW.[11] For the purposes of direct comparison with the previous editions of the *World Small Hydropower Development Report (WSHPDR)*, the up to 30 MW definition of SHP will be used in this chapter. Compared to the *WSHPDR 2019*, installed capacity increased by 11 per cent due to the introduction of new plants. The potential capacity changed based on a more accurate estimate of inventoried potential and new studies carried out on previously not studied rivers (Figure 5).[19] A list of recently commissioned SHP projects is displayed in Table 2.

Figure 5. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2021 in Brazil (MW)**



Sources: ANEEL,[11] ABRAPCH,[18] *WSHPDR 2019*,[19] *WSHPDR 2013*,[20] *WSHPDR 2016*[21]

Note: Data for SHP up to 30 MW.

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

Name	*Location*	*Capacity [MW]*	*Operator*	*Launch Year*
Paraíso	Paraíso	1.0	HIDRELÉTRICA PARAÍSO	2020
Jph Catete	Nova Friburgo	1.8	JPH Empreendimentos e Participações LTDA	2020
São Domingos Do Prata	Vista Alegre do Prata	2.2	Usina São Domingos do Prata LTDA	2020
Bandiera Ronfim	Corbélia	2.2	CGH Bandiera Ronfim Geração De Energia LTDA	2020
Serra Velha	Agrolândia	2.5	Hidrelétrica Serra	2020
Ponte Serrada	Passos Maia	4.1	PONTE SERRADA GERAÇÃO DE ENERGIA	2020
Igrejinha	Boa Vista do Cadeado, Jóia	4.9	Boa Vista Do Cadeado	2020
Rio Tigre	Guatambú	5.0	Centrais Elétricas Rio Tigre	2020
Bedim	Marmeleiro, Renascença	6.0	SANTANA	2020
Beleza	Juscimeira	6.5	ENERGETICA PCH	2020
Sede II	Ijuí	7.9	IJUÍ CENTENÁRIA GERAÇÃO	2020
Barra das Águas	Faxinal dos Guedes, Xavantina	8.5	PCH ÁGUAS DO RIO IRANI ENERGÉTICA	2020
Morro Grande	Muitos Capões	9.8	HIDRELÉTRICA MORRO	2020
Piarucum	Dianópolis, Novo Jardim, Ponte Alta do Bom Jesus	10.0	PIARUCUM	2020
Rincão	Entre-Ijuís	10.0	RINCÃO ENERGIA	2020

Name	*Location*	*Capacity [MW]*	*Operator*	*Launch Year*
ITAPOCUZ-INHO IIA	Jaraguá do Sul, Joinville	11.7	RIBEIRAO MANSO	2020
Salto do Guassupi	Júlio de Castilhos	12.2	Salto do Guassupi Energética	2020
Poço Fundo	São José do Vale do Rio Preto	14.0	POÇO FUNDO ENERGIA	2020
Tamboril	Cristalina	15.8	SÃO BARTOLOMEU GERADORA DE ENERGIA RENOVÁVEL	2020
Quebra Dentes	Júlio de Castilhos, Quevedos	22.4	Quevedos Energética	2020

Source: ANEEL[11]

The definition of 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.[22] Furthermore, the maximum reservoir area was limited to 13 km² (excluding the regular riverbed). In case of a reservoir area exceeding 13 km², the plant is still considered an SHP plant if this 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 the notification of ANEEL. This serves as an important incentive for SHP plants below 3 MW, although they are still required to abide by environmental and other state regulations.[23]

Law No. 13.360 of 17 November 2016 established a new definition of SHP as plants with an installed capacity from 5 MW to 30 MW.[23] However, the plants from 3 MW to 5 MW that were commissioned before the new law are still classified as SHP. Therefore, the actual installed capacity of all hydropower plants considered as SHP in the country 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 grants for hydropower projects between 5 MW and 50 MW that do not have all the characteristics of SHP plants listed above.[24] 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.[25,26] This means that more SHP plants can be considered as distributed generation plants and can enjoy the regulatory advantages available to this kind of generation, which were previously established by Resolution No. 673, including a simplified licensing process and access to the net metering tariff. 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.[25,26]

According to The Brazilian Ten-Year Plan for Energy Expansion 2029 (Plano Decenal de Expansão de Energia 2029, PDE 2029), the Government predicts that the installed capacity of SHP will reach 9,045 MW (4 per cent of total installed capacity) in 2029. As of 2021, the installed capacity of SHP in Brazil (6,324.6 MW) represented 3.6 per cent of total installed capacity and 93 per cent of the 2021 SHP installed capacity target of 6,787 MW.[27] 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 from 11 per cent in January 2021 to 17 per cent in 2029, based on the assumption that the available incentives, such as tax exemptions, stay in place and continue to have a positive impact on the development of the source.[27] Several planned SHP projects are listed in Table 3.

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

Name	*Location*	*Capacity [MW]*	*Developer*	*Development Stage*
Amarají	Pernambuco, Amarají River	8.5	Usina União e Indústria S.A	Intention of grant registered
Bom Jesus	Mato Grosso, Tadarimana River	8.8	Bom Jesus Agropecuária Ltda.	Intention of grant registered
Catanduva	Paraná, Iratim River	18.0	Catanduva Geração de Energia Ltda.	Executive Summary adequated
Água Branca	Paraná, Alto Ribeira River	22.0	Valdevir Gromowsk	Intention of grant registered
Brito	Minas Gerais, Pirange River	23.0	Petraprime Gestão e Administração de Propriedade Imobiliária Ltda.	Intention of grant registered

Source: ANEEL[11]

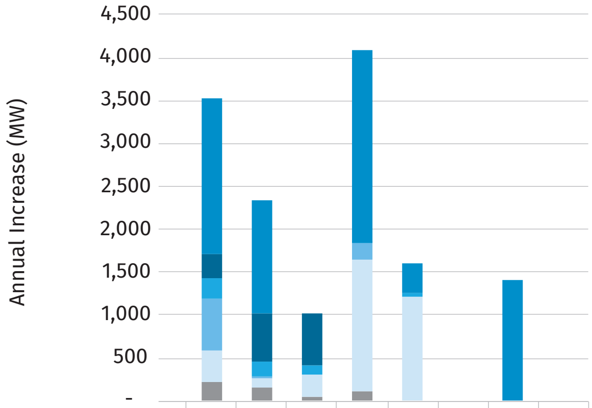
SHP represents a renewable energy alternative which brings several benefits to the energy sector of Brazil, such as synergy with other sources as well as flexibility of operation and storage. Often, SHP also brings social and economic development to the areas where the plants are installed. In most cases, SHP entrepreneurs are required to invest in some local improvements as a mitigation measure for the environmental impact caused by the project. In particular, electrification through development of SHP in Brazil has been correlated with broad-based job creation and increases in labour productivity in the affected regions.[28,29] Although possible negative consequences of SHP development are reduced by the above measures, the general public in Brazil seems to associate the disadvantages of large hydropower with SHP as well. This has a significant negative impact on the public perception of SHP in the country and, therefore, on 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 one of the major programmes to promote renewable energy sources in Brazil. The programme's primary focus was on biomass, wind power and SHP. This programme was similar to a feed-in tariff scheme, but was aimed at 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 and the programme has been discontinued. The current mechanism to promote renewable energy sources in Brazil is through power auctions. Specific auctions are offered for a restricted group of energy sources, serving as an incentive for large-scale projects. Additionally, the net metering model was chosen for on-site generation, benefiting mainly the solar photovoltaics market.

In the last few years, wind power projects have been showing lower prices in the auctions and the construction and operating 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 does wind power and solar power equipment (e.g., the tax on circulation of goods and services). As a result of the balance of relative costs and incentives benefitting primarily large projects and non-hydropower renewable energy sources, SHP has lately been losing its share of the energy mix to other renewable sources. The Ten-Year Energy Expansion Plan 2029 (PDE 2029) of Brazil shows that SHP projects contracted as of 2019 were to account for only 6 per cent of the total power generation capacity to be commissioned in 2020, less than 8 per cent in 2021, 11 per cent in 2022, 0.2 per cent in 2023 and 2 per cent in 2024. Considering the entire period from 2020 to 2029, SHP represents only 4 per cent of the total contracted capacity, while wind power and solar photovoltaics represent 25 per cent and 10 per cent, respectively (Figure 6).[27] Although these data demonstrate that currently solar and wind power are growing faster than SHP, the PDE 2029 also indicates a wide range of SHP projects not yet developed that may be important for the energy expansion.

Figure 6. **Contracted Capacity Expansion in Brazil until 2029**



	2020	2021	2022	2023	2024	2025	2026	2027
Thermal Power	1,802	1,305	-	2,238	363	-	1,405	-
Photovoltaic Power	298	557	585	-	-	-	-	-
Hydropower < 30MW	225	177	111	10	38	-	-	-
Hydropower > 30MW	611	36	-	204	-	-	-	-
Wind Power	353	107	264	1,521	1,212	-	-	-
Biomass and Biogas	231	147	50	115	-	-	-	-

Source: EPE[27]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

The current environmental licensing process for SHP presents some barriers for development. 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.[30] SHP projects between 10 MW and 30 MW therefore require an Environmental Impact Assessment (Estudo de Impacto Ambiental, EIA) and an Environmental Impact Report (Relatório de Impacto Ambiental, RIMA).

SHP projects between 3 MW and 10 MW, however, are only required to prepare a Simplified Environmental Report (Relatório Ambiental Simplificado, RAS). Hydropower plants below 3 MW have to go through an even less rigorous process of environmental licensing. On the other hand, SHP projects of this size are generally considered expensive and unattractive to investors. It should be noted that the limit of 3 MW set by the Environmental Law is lower than the 5 MW maximum capacity limit of SHP plants for distributed generation established by the ANEEL Normative Resolution No. 786. This is due to the fact that in Brazil environmental laws are treated separately from the laws on incentives for energy sources. Overall, the environmental licensing process for wind power and solar photovoltaic projects is faster and simpler than for SHP, serving as another incentive for these two renewable energy sources to the detriment of SHP.

Nonetheless, there are additional instruments of support for SHP as well. The 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 tax on land use for inundation;
- Incentives for distributed generation (plants up to 5 MW);
- Energy Reallocation Mechanism (MRE), in which SHP plants can participate optionally.

Despite the huge hydropower potential available in Brazil and the extensive national experience in hydropower generation, the current policies and financial mechanisms do not seem to provide an adequate market for the expansion of SHP. In contrast, wind power and solar photovoltaic power have recently been the main focus of policies promoting the expansion of renewable energy sources, with remarkable results. In the short term no changes to this scenario are expected. The stabilization of the relatively new renewable energy sources (solar photovoltaic power and wind power) in the national market is likely required in order for more competitive conditions for the expansion of the SHP plants to emerge.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

According to several studies published as part of the 2015 report "Scenarios and Alternatives for Adaption to Climate Change", climate change is expected to have severe impacts on the operation of existing hydropower plants in Brazil and the viability of planned projects. In particular, river flow to the country's four largest hydropower plants (Itaipu, Furnas, Sobradinho and Tucuruí) is expected to decrease by 38-57 per cent by 2040. The flow of the Xingu River in Amazonia feeding into the Bel Monte hydropower plant, currently nearing completion, is expected to decrease by between 25 and 55 per cent. This threatens the viability of the project, which is already expected to operate below full capacity due to seasonal flow variability.[31]

The Amazon region is expected to be hit particularly hard by climate change due to ongoing deforestation. A recent study of the climate change impacts on hydropower for the period 2026–2045 relative to the baseline period 1986-2005 in the Tapajós basin, much of which is run-of-river and highly sensitive to seasonal flow variability, projected a loss in generation of 312-430 GWh per month during the dry season. It also suggests a delay in the peak generation period by 22–29 days as well as an increase in interannual generation variability from 548 GWh to 713–926 GWh due to the combined effects of deforestation and climate change. The study additionally underlines that smaller hydropower projects are less prone to large-scale miscalculations of expected capacity in conditions of climate uncertainty.[32]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

SHP projects are currently in a disadvantaged position in Brazil 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 the environmental licensing process for plants between 10 MW and 30 MW;
- High cost of constructing and operating SHP plants in comparison to other renewable energy sources such as wind and solar power in the context of Brazil;
- 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, mainly due to campaigns against large hydropower plants.

Factors enabling the development of SHP in Brazil include:

- A long history of hydropower development;
- Abundant unrealized SHP potential;
- Regulatory and licensing incentives for SHP below 5 MW, especially for SHP below 3 MW, and discounts/exemptions in the case of certain fees and taxes.

REFERENCES

1. Brazilian Institute of Geography and Statistics (IBGE) (2018). *Projections of the population of Brazil and federal units by sex and age: 2010-2060*. Available at https://ftp.ibge.gov.br/Projecao_da_Populacao/Projecao_da_Populacao_2018/projecoes_2018_populacao_2010_2060_20200406.xls [in Portuguese] (Accessed 21 May 2021).
2. Brazilian Institute of Geography and Statistics (IBGE) (2020). *Territorial Areas*. Available at https://www.ibge.gov.br/geociencias/organizacao-do-territorio/estrutura-territorial/15761-areas-dos-municipios.html [in Portuguese] (Accessed 21 May 2021).
3. Brazilian Institute of Geography and Statistics (IBGE) (2016). *Geosciences: IBGE revises the altitudes of seven culminating points.* Available at https://agenciadenoticias.ibge.gov.br/agencia-sala-de-imprensa/2013-agencia-de-noticias/releases/15275-geociencias-ibge-reve-as-altitudes-de-sete-pontos-culminantes [in Portuguese] (Accessed 21 May 2021).
4. Encyclopaedia Britannica (2021). *Brazil, Relief.* Available at https://www.britannica.com/place/Brazil#ref25059 (Accessed 21 May 2021).
5. Brazilian Institute of Geography and Statistics (IBGE) (2002). *Climate map of Brazil*. Available at https://geoftp.ibge.gov.br/informacoes_ambientais/climatologia/mapas/brasil/Map_BR_clima_2002.pdf [in Portuguese] (Accessed 21 May 2021).
6. Cavalcanti, I.F.A., Ferreira, N.J., da Silva, M.G.A.J. & Dias,

M.A.F.S. (2009). *Weather and Climate in Brazil 2009*. São Paulo: Oficina de Textos. pp. 464. [in Portuguese]
7. Climate Links (2018). *Climate Risk Profile: Brazil*. Available at https://www.climatelinks.org/sites/default/files/asset/document/2018-April-30_USAID_CadmusCISF_Climate-Risk-Profile-Brazil.pdf (Accessed 21 May 2021).
8. Brazil Geological Service - Mineral Resource Research Company (CPRM) (2011). *Pluviometric Atlas of Brazil*. Available at http://www.cprm.gov.br/publique/Hidrologia/Mapas-e-Publicacoes/Atlas-Pluviometrico-do-Brasil-1351.html [in Portuguese] (Accessed 21 May 2021).
9. Brazilian Institute of Geography and Statistics (IBGE) (2018). *Rivers of Brazil*. Available at https://educa.ibge.gov.br/jovens/conheca-o-brasil/territorio/18305-rios-do-brasil.html [in Portuguese] (Accessed 21 May 2021).
10. Brazilian Institute of Geography and Statistics (IBGE) (2007). *IBGE participates in the mapping of the true source of the Amazon River.* Available at https://censo2010.ibge.gov.br/noticias-censo.html?busca=1&id=1&idnoticia=908&t=ibge-participa-mapeamento-verdadeira-nascente-rio-amazonas&view=noticia [in Portuguese] (Accessed 21 May 2021).
11. National Agency of Electric Energy (ANEEL) (2021). *ANEEL Generation Information System (SIGA)*. Available at https://www.aneel.gov.br/siga [in Portuguese] (Accessed 21 May 2021).
12. Power Research Company (EPE) (2020). *National Energy Balance (BEN) 2020*. Available at https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-479/topico-528/BEN2020_sp.pdf [in Portuguese] (Accessed 21 May 2021).
13. World Bank (2020). *Access to electricity (% of population) - Brazil*. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=BR&view=chart (Accessed 21 May 2021).
14. Silva, B. G. (2011). *Evolution of the Brazilian electricity sector in the national economic context: a historical and econometric long-term analysis*. Dissertation (Master in Sciences) - Postgraduate Program in Energy of the University of São Paulo. p. 162. Available at http://www.teses.usp.br/teses/disponiveis/86/86131/tde-12032012-091848/pt-br.php [in Portuguese] (Accessed 22 May 2021).
15. Power Research Company (EPE) (2017). *Processing of contributions to public consultation 33/2017*. Available at 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 [in Portuguese] (Accessed 22 May 2021).
16. Chamber of Electric Energy Commercialization (CCEE) (n.d.). *Our relationships*. Available at https://www.ccee.org.br/portal/faces/pages_publico/onde-atuamos/com_quem_se_relaciona?_adf.ctrl-state=1a9y6qv222_1&_afrLoop=30584853293416 [in Portuguese] (Accessed 26 May 2021).
17. National Agency of Electric Energy (ANEEL) (2021). *Consumer and distribution revenue reports*. Available at https://www.aneel.gov.br/relatorios-de-consumo-e-receita [in Portuguese] (Accessed 26 May 2021).
18. Brazilian Association of Small Hydropower Plants and Hydroelectric Generators (ABRAPCH) (2020). *National conference of SHP and HEG discusses renewable energy scenario in Curitiba*. Available at https://abrapch.org.br/2020/03/conferencia-nacional-de-pchs-cghs-discute-cenario-da-energia-renovavel-em-curitiba/ [in Portuguese] (Accessed 22 May 2021).
19. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
20. UNIDO, ICSHP (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
21. UNIDO, ICSHP (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
22. National Agency of Electric Energy (ANEEL) (2015). *Normative resolution No. 673 of 4 August 2015.* Available at http://www2.aneel.gov.br/cedoc/ren2015673.pdf [in Portuguese] (Accessed 22 May 2021).
23. Government of Brazil (2016). *Law No. 13.360 of 17 Novembro 2016*. Available at http://www.planalto.gov.br/ccivil_03/_ato2015-2018/2016/lei/L13360.htm [in Portuguese] (Accessed 22 May 2021).
24. National Agency of Electric Energy (ANEEL) (2017). *Normative resolution No. 765 of 25 April 2017*. Available at http://www2.aneel.gov.br/cedoc/ren2017765.pdf [in Portuguese] (Accessed 22 May 2021).
25. National Agency of Electric Energy (ANEEL) (2012). *Normative resolution No. 482 of 17 April 2012*. Available at http://www2.aneel.gov.br/cedoc/ren2012482.pdf [in Portuguese] (Accessed 22 May 2021).
26. National Agency of Electric Energy (ANEEL) (2015). *Normative resolution No. 786 of 17 October 2017*. Available at http://www2.aneel.gov.br/cedoc/ren2017786.pdf [in Portuguese] (Accessed 22 May 2021).
27. Power Research Company (EPE) (2020). *Ten-Year Energy Expansion Plan 2029 (PDE 2029)*. Available at https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/Documents/PDE%202029.pdf [in Portuguese] (Accessed 22 May 2021).
28. Pizzol, C.C.S. (2011). *Projection of market growth for small hydroelectric plants (SHP) in Brazil*. Dissertation (Master in Energy Engineering) - Federal University of Itajubá, Itajubá, 2011. Available at https://repositorio.unifei.edu.br/jspui/handle/123456789/1308 [in Portuguese] (Accessed 22 May 2021).
29. Barham, T., Lipscomb, M. & Mobarak, A. M. (2011). *Development Effects of Electrification: Evidence from the Geologic Placement of Hydropower Plants in Brazil.* CAF Working document No. 2011/03. Available at https://www.academia.edu/download/40607990/Development_Effects_of_Electrification_E20151203-16020-13z4pir.pdf (Accessed 22 May 2021).
30. Government of Brazil (1986). *CONAMA Resolution No. 001 of 23 January1986*. Available at http://www2.mma.gov.br/port/

conama/res/res86/res0186.html [in Portuguese] (Accessed 23 May 2021).
31. Banford, S. (2015*). Brazil climate change report warns of failed hydropower and crops*. Mongabay. Available at https://news.mongabay.com/2015/11/brazil-climate-change-report-warns-of-failed-hydropower-and-crops/ (Accessed 23 May 2021).
32. Arias, M.E., Farinosi, F., Lee, E., Livino, A., Briscoe, J. & Moorcroft, P.R. (2020). Impacts of climate change and deforestation on hydropower planning in the Brazilian Amazon. *Nature Sustainability, 3*(6), 430–436.

Chile

Patrick Furrer, Jorge Saavedra and Patricio Muñoz, AFRY Chile

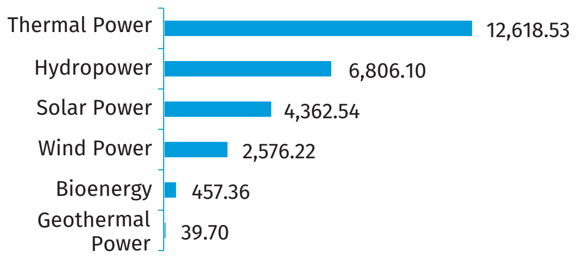
KEY FACTS

Population	19,116,209 (2020)[1]
Area	756,100 km² (continental territory), 2,006,096 km² (continental, Antarctic and insular)[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. The highest peak is the Ojos del Salado at 6,893 metres in elevation. Between continental and southern Chile there is a submerged mountain range whose highest peaks emerge to form islands, eventually reaching the north-eastern tip of the Antarctic peninsula. Rapa Nui Island (Easter Island) presents a relief characterised by plains and volcanoes.[2,3]
Climate	Chile has a variety of climates: desert, Mediterranean steppe, warm temperature 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 has a subtropical climate with oceanic influence characteristics. Temperatures vary depending on the region; in the north, daily averages range from 12 to 23 °C. The central region average daytime temperatures range from 9 to 21 °C depending on the time of year, while in the south, average daily temperatures range from 2 to 16.8 °C.[2,4]
Climate Change	As a consequence of climate change, several studies have projected a significant decrease in mean monthly flows between the Region of Coquimbo and Region of Los Lagos (from 30° to 42° South) and an increase in the elevation of the zero isotherm, which implies a reduction of the water storage of nivo and nivo-pluvial basins as well as an increase in the risk of flood and landslide events.[5]
Rain Pattern	Rainfall varies in amount and distribution across the territory and increases towards the south. In the 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, the rivers are short, with steep slopes, low-flow, torrential and are unsuitable for navigation, but have great hydropower potential. The northern rivers are fed by snow thawing, the central ones have a mixed feeding, the southern ones by rainfall and the austral ones have mixed regimes, fed by rain and thawing glaciers. The longest river is the Lao river of 440 km, spanning the Andean mountain range and the Atacama desert. It has several main tributaries: the Salado River, the San Salvador River and the San Pedro de Inacaliri River. The next longest river is the Bío-Bío River, stretching 380 km from lakes Icalma and Galleutué, through the Andean valley. Both the Lao and the Bío-Bío rivers drain into the Pacific Ocean.[26]

ELECTRICITY SECTOR OVERVIEW

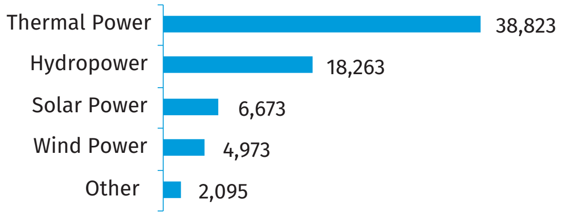
In October 2021, the total installed generating capacity of Chile was 26,653 MW (Figure 1), of which 99 per cent corresponded to the National Electrical System (SEN).[7] Hydropower is the most important source of electricity in Chile, making up 27 per cent of the total installed capacity. The total electricity generated in 2020 was 70,828 GWh (Figure 2).[8] There is a noticeable trend towards an increase in renewable energy generation, mainly in wind and solar power. As a result of the Paris agreement commitments by the government of Chile, there is a plan to decarbonize the energy mix; currently, there is an agreement to shut down 11 coal power plants by 2024, which represents 1,731 MW and 31 per cent of the total capacity of coal power plants.[9] An even more ambitious plan for accelerated decarbonization is also under discussion, but is not yet approved because of the possible marginal cost increases this would bring.

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



Source: CNE[10]

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



Source: NCE[8]

In the 1970s began the privatization and segmentation of the Chilean electricity market, starting with the distribution segment (originally owned by the Chilean National Electricity Company, ENDESA), followed by the generation and transmission segments, which were privatized and afterwards separated in the mid-1990s. Generation, transmission and distribution are unbundled horizontally. The sectors are, however, integrated vertically. Electricity system prices follow a marginalist approach and there are nodal prices given the grid constraints. Until 2005, the generation segment was dominated by three national companies, Enel (formerly ENDESA Chile), AES Gener (formerly GENER) and Colbún. The situation has changed substantially with the appearance of other competitors (medium- and small-sized players) with more than 400 generation companies currently active in the Chilean energy market.

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). SEN serves approximately 98 per cent of the country's population. Other smaller networks are the Aysén System (SEA), Los Lagos generating unit and Magallanes System (SEM).

The transmission system can transport electricity from generating plants located throughout the country to distribution companies' substations 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 historical major players — TRANSELEC, ENGIE (Suez, E-CL), TRANSNET (CGE), ENEL (Chilectra) — as well as one new player INTERCHILE since the construction of the 500 kV system. At the moment of writing of this chapter, there was a bid for a HVDC line of ±600 kV between the Kimal and Lo Aguirre substations, which will improve the transport of electricity between the north and the central system of Chile. In terms of regional interconnections, an interconnection exists between the north of the country and Salta province in Argentina. The line has a length of 408 kilometres, 345 kV of rated voltage and is connected between the substations of Andes and Cobos (both owned by AES). According to the National Electrical Coordinator (CEN), the line is still awaiting approval and consequently there is no power flow registered for the moment.

The distribution system is principally in the hands of four companies: ENEL, CGE, Chilquinta and SAESA. The distribution system, consisting of lines, substations and equipment, is established in two voltage ranges (medium and low voltage). In the low voltage range, there are three rated voltages defined by the Chilean regulations. It is usual to use 380 V and 220 V in three-phase and single-phase installations, respectively:

- 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.[11]

As established by the General Services Law, the main bodies involved in regulating the electricity market are:

- 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 sector, ensuring compliance and advising the Government on all matters related to energy;
- National Commission Energy: a public and decentralized body, with its own assets and full capacity to acquire and exercise rights and obligations. Its function is to analyze 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;
- Electricity and Fuel Superintendence (SEC): the public agency responsible for overseeing the energy market, in order to have safe and quality products and services, as well as supervising compliance with electrical regulations in the country;
- National Electrical Coordinator (CEN): an independent body responsible for ensuring the security of the service in the electrical system, guaranteeing the most economical operation for all system installations, and planning the development of the transmission system. Additionally, it adopts the pertinent measures to monitor the chain of payments of the economic transfers subject to their coordination, guaranteeing their continuity;
- Panel of experts: 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 indicated in the General Law of Electrical Services (studies, tariffs, plans, etc.), and in other laws on energy matters;
- Ministry of Environment: the body that grants the approval of the environmental impact studies for projects in the sector;
- Municipalities: they oversee the issue of permits for the use of public assets.[9,12,13,14,15,16,17]

The average sale price of electricity (average node price in SEN) in December 2020 was 58.56 CLP/kWh (42.16 USD/MWh).[18] This value, however, does not consider the costs of distribution or the charge for the use of the national transmission system.

SMALL HYDROPOWER SECTOR OVERVIEW

Chilean Law No. 20.257 defines a small hydropower (SHP) plant as a hydropower plant with a maximum installed capacity of below 20 MW.[19] SHP is considered as 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 (Table 1).

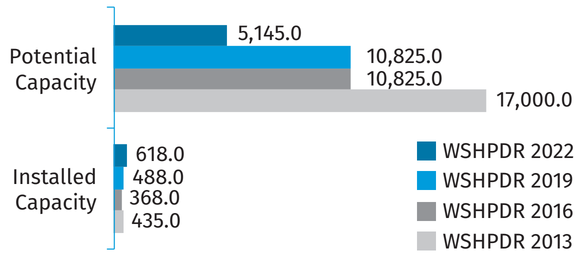
Table 1. **Classification of Small Hydropower in Chile**

Category	*Installed capacity*
Micro	5 kW–100 kW
Mini	100 kW–1 MW
Small	1 MW–20 MW

Source: Ministry of Energy [20]

The available capacity of SHP up to 20 MW as of January 2021 was 618 MW, distributed among 130 plants (Table 2). For SHP up to 10 MW, the installed capacity was 304 MW from 110 plants.[21] In comparison to data from the *World Small Hydropower Development Report (WSHPDR)* 2019, installed capacity has increased by almost 27 per cent (Figure 3). Conversely, the estimated potential has decreased due to new data made available, based on improved analytical methods and reflecting shrinking water availability in the country.[22] Additionally, in 2020 there were 77 MW of SHP under construction and 779 MW of SHP project with an Environmental Qualification Resolution (RCA), meaning that they had a permission to start SHP construction.[23]

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



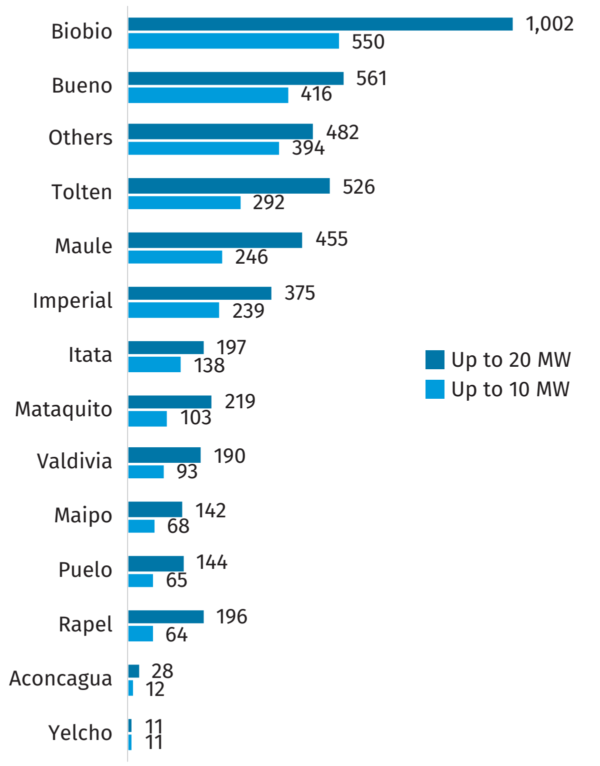
Source: NEC,[16] Ministry of Energy, General Directorate of Water & University of Chile,[21] *WSHPDR 2013,*[24] *WSHPDR 2016,*[25] *WSHPDR 2019*[26]

Note: Data for SHP up to 20 MW.

The increase in the installed capacity of SHP was mainly due to regulatory changes in Decree 244, which regulates small, distributed power plants, referred to as PMG(D)s (Pequeños Medios de Generación, Distribuida) in Chile. It has simplified the processing of projects of less than 9 MW connected to the distribution network, particularly for projects under 1.5 MW that have no significant impact on the grid (known as INS in Chile). INS projects allow avoiding some electrical studies and steps to follow for the connection, which helps avoid important costs in the processing of the projects.[27]

The estimated SHP undeveloped potential up to 10 MW is equivalent to 2,691 MW and for SHP up to 20 MW is 4,527 MW (Figure 4). The most promising rivers are the Biobio (550 MW and 1,002 MW), Bueno (416 MW and 561 MW) and Tolten (292 MW and 526 MW).[17] This corresponds to the technical potential, 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 part of the country (Aysén region) due to environmental restriction.[28] For SHP up to 10 MW, the total technical potential (including developed capacity) was estimated at 2,995 MW and for hydropower plants up to 20 MW at 5,145 MW.[17] An additional potential associated with reservoirs used for irrigation works was studied in 2007 for Rights of Use of Consumptive Water and is estimated at 866 MW. Of the known potential, 558 MW of capacity has less than 20 MW and flows above 4 m^3/s.[29] Planned projects on these sites can be seen in Table 3.

Figure 4. **Estimated Potential of Small Hydropower up to 10 MW and 20 MW by River in Chile (MW)**



Source: Ministry of Energy, General Directorate of Waters & University of Chile21

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

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Plant type*	*Operator*	*Launch year*
Hp mocho	Río Bueno, Región de Los Ríos	15.45	–	Run-of-river	Hidromocho sa	2021/2022
Pmgd hp panguipulli	Panguipulli, Región de Los Ríos	0.35	–	Run-of-river	Latinoamericana	2021/2022

Name	Location	Capacity (MW)	Head (m)	Plant type	Operator	Launch year
Pmgd hp viña tarapacá	Isla de Maipo, Región Metropolitana de Santiago	0.25	–	Run-of-river	Andes energy capital	2021/ 2022
Pmgd hp central hidroeléctrica chilco	Lago Ranco, Región de Los Ríos	0.20	–	Run-of-river	Ganadera y forestal carran ltda	2021/ 2022
Pmgd hp el brinco	Mulchén, Región del Biobío	0.12	–	Run-of-river	Hidro munilque spa.	2021/ 2022
Pmgd hp el manzano (pelarco)	Pelarco, Región del Maule	0.15	–	Run-of-river	Central hidroelectrica el manzano spa	2021/ 2022
Hp palmar	Puyehue, Región de Los Lagos	8.57	–	Run-of-river	Hidropalmar s.a.	2020
Hp correntoso	Puyehue, Región de Los Lagos	8.38	–	Run-of-river	Hidropalmar s.a.	2020
Pmgd hp la compañía ii	Codegua, Región del Libertador Gral. Bernardo O'Higgins	2.56	–	Run-of-river	Empresa eléctrica la compañía spa	2020
Ch cochamo	Cochamó, Región de Los Lagos	0.68	158.0	Run-of-river	Sagesa s.a.	2020
Pmgd hp cosapilla	Putre, Región de Arica y Parinacota	0.50	–	Run-of-river	Engie	2020
Hp cumbres	Río Bueno, Región de Los Ríos	17.86	–	Run-of-river	Cumbres s.a.	2019
He convento viejo	Chimbarongo, Región del Libertador Gral. Bernardo O'Higgins	16.00	–	Reservoir	Embalse convento viejo s.a.	2019
Hp dos valles	San Fernando, Región del Libertador Gral. Bernardo O'Higgins	4.45	–	Run-of-river	Hidroelectrica dos valles spa	2019
Hp palacios	San Fernando, Región del Libertador Gral. Bernardo O'Higgins	3.02	–	Run-of-river	Hidroelectrica palacios spa	2019
Pmgd hp msa-i	Villarrica, Región de La Araucanía	3.00	–	Run-of-river	Minicentrales araucania s.a.	2018
Pmgd hp santa elena	Cunco, Región de La Araucanía	2.75	–	Run-of-river	Central hidroeléctrica santa elena s.a.	2018
Hp alto renaico	Mulchén, Región del Biobío	1.38	–	Run-of-river	Espinos s.a	2018
Hp río colorado	San Clemente, Región del Maule	16.47	–	Run-of-river	Rio Colorado	2017
Pmgd hp melo	Quilleco, Región del Biobío	2.97	–	Run-of-river	Socer s.a.	2017

Source: CEN[20]

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

Name	Location	Capacity (MW)	Head (m)	Plant type	Developer	Planned launch year	Stage of Development
Río Maño	Panguipulli, Región de Los Ríos	3.0	80	Run-of-river	Bosch Rivera Limitada	2021	In environmental evaluation
El Portal	Mulchén, Región del Biobío	1.2	12.8	Run-of-river (irrigation canal)	CENTRAL EL ATAJO SPA	2021	Approved environmental evaluation
Llancalil	Pucón, Región de la Araucanía	6.9	105	Run-of-river	Inversiones Huife Ltda.	--	In environmental evaluation
Las Nieves	Melipeuco, Región de la Araucanía	6.5	400	Run-of-river	Hidroeléctrica Las Nieves SPA	2021	Under construction
Pasada Cipresillos	Machalí, Región del Libertador General Bernardo O´Higgins	9	336	Run-of-river	Eléctrica Cipresillos	2021	Under construction

Source: Environmental Evaluation System[30]

Table 4 displays sites with hydropower potential, however, there is no public information on whether there are any planned SHP projects on these sites. As investment in generation projects is private, in most cases, SHP projects are made public when they enter the Environmental Evaluation System.

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

Name	*Location*	*Potential capacity (MW)*	*Head (m)*	*Type of project*	*Type of site (new/refurbishment)*
Río Cautín	Curacautín, Región de la Araucanía	15.6	36	Run-of-river	New
Estero Cañileo	Quilleco, Región del Biobío	6.3	125	Run-of-river	New
Los Pellines	Coihueco, Región de Ñuble	3.8	197	Run-of-river	New
Río Longaví	Longaví, Región del Maule	13.2	100	Run-of-river	New
Río Ancoa	Linares, Región del Maule	5.4	288	Run-of-river	New

Source: Ministry of Energy, General Directorate of Waters & University of Chile[17]

Table 5. **Definition of Renewable Non-Conventional Energy Generators in Chile**

Classification	*Meaning*
Small distributed generation plant (PMGD)	Plants ≤ 9 MW, connected to the facilities of a distribution company
Small generation plant (PMG)	Plants ≤ 9 MW, connected to the facilities of a transmission system
Non-conventional generation plant (MGNC)	Non-conventional renewable energy plants ≤ 20 MW; the MGNC category is not exclusive with the above categories indicated.

Source: Ministry of Economy, Development and Reconstruction[30]

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.[31] This process concluded with the Roadmap 2050 and the 2050 Energy Policy.[32,33] These documents are based on four main objectives, including generating 60 per cent of energy from renewable sources by 2035 and 70 per cent by 2050.

In 2018, the Ministry of Energy published Energy Route 2018–2022, a roadmap for the four years of the new Government with seven lines of action: energy modernization (regulation and institutions), socialization of the projects, energy sector development, grid diversification with local low-emission energy, efficiency and electrification of transport, residential and industrial sector energy efficiency and energy education and capacity building.[34] Achievements include time reduction in the environmental approval process and the elaboration of a master plan for decommissioning or reconversion of coal power plants.

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

Ministry of Economy Decree 244 regulates the mini- and small hydropower sector, which belongs to the category of non-conventional renewable energy (ERNC) generators along with geothermal power, wind power, solar power, biomass and co-generation (Table 5).[9]

Law 19.940 includes the fee for small ERNC generators access to the transmission system and regulates the cost for the connection of small distributed ERNC generators to the distribution systems. Law 20.018 requires that energy generators provide at least 5 per cent of their energy through sustainable means or purchase the equivalent from renewable sources. This percentage is set to rise to 10 per cent by 2024.

Currently, a controversial amendment of the Chilean Water Code is under discussion in the National Congress.[35] The amendment project aims to modify the concept of water rights in order to: limit their exercise; make them temporary (20 or 30 years, with the possibility of renewal); limit the exercise of water rights in the event of scarcity situations; establish a "use it or lose it" clause; facilitate the Government's intervention into hydrological areas and reform the non-use fee payment.

Law 19.300 on the general bases of environment requires that every energy generation plant with a capacity larger than 3 MW and a transmission line with voltage greater than or equal to 23 kV together with its substations must enter the system of environmental impact evaluation (SEIA). Projects that enter the SEIA must present an Environmental Impact Declaration, unless their impacts significantly change or intervene in some aspects defined in the law (population health, renewable natural resources, community resettlement and landscape value). In such cases, a full Environmental Impact Evaluation must be presented. In general, SHP projects present an Environmental Impact Declaration.

Law 20,698 was published in 2013 with the main goal of extending the energy mix by incorporating ERNC generation projects. This law set new goals for ERNC generation, changing the target share from 10 per cent by 2024 to 20 percent by 2025. Also, the Ministry of Energy has to make public tenders for annual blocks of energy provided by ERNC sources.

In 2016, Law 20,936 creating a new electric transmission system and an independent coordination agency of the national electric system was published. The main objectives of this law were to increase competition in the electric market, remove entry barriers to the energy generation market and boost the development of ERNC.

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.

COST OF SMALL HYDROPOWER DEVELOPMENT

The development of SHP projects must consider different factors, such as water rights availability, environmental impacts, access roads, hydrological and geotechnical conditions, which are specific to the project location. The cost of SHP development is highly dependent on the project's location.[36]

Based on information provided by developers of generation projects, the National Commission of Energy has estimated the average development cost of run-of-river SHP plants (up to 20 MW) to be 3,263 USD/kW. The average variable cost depending on energy generation is estimated at 1.3 USD/MWh and the operational and maintenance cost non-related to energy generation is 1 per cent of the total expenditure. The total time of construction was estimated as three years.[32]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

In Chile, state financial mechanisms are provided mainly by the Corporation of Production Development (CORFO) and do not target specifically SHP but ERCN projects in general. CORFO created a special credit scheme to finance investment into construction, operation and commissioning of ERCN projects, with a maximum financing amount of USD 15 million.[37] In 2020, as a measure to mitigate the economic effects of the Covid-19 crisis, CORFO created a Green Credit to boost ERCN projects, energy efficiency and circular economy, with a maximum financing amount of USD 7 million for ERCN generation projects.[38]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Chile is highly vulnerable to climate change and meets most of the nine vulnerability criteria set by the United Nations Framework Convention on Climate Change (UNFCCC). Hydropower generation potential is expected to decrease by 11 per cent between 2011 and 2040 and by 22 per cent between 2071 and 2099 under the emission scenario A2 and by 10 and 16 per cent for the same periods, respectively, under the emission scenario B2.[3]

One measure to mitigate the effects of climate change on SHP is to add more flexibility by incorporating new technologies, such as using lithium-ion batteries to store energy. An example of this is the Virtual Dam initiative of AES Gener that installed batteries providing 10 MW for five hours at the run-of-river plant Alfalfal I (178 MW).[39] This initiative could be replicated at a smaller scale for SHP plants.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Chile has abundant energy resources and has made some effort in order to promote the development of renewable energy technologies, including SHP. However, there are barriers to their development and implementation. Regarding SHP, there are social, institutional and technical barriers, including the following:

- 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, in particular, with other productive uses, conservation and tourism;
- Asymmetry of information: Lack of information and good communication between the community and the developers generates mistrust;
- Balance of cost, risks and benefits: Lack of information within the communities about the cost, potential risks and real benefits associated with SHP projects generates the sensation of being robbed of their resources. The communities see only the external cost and usually overestimate the potential risks and revenues for the developer;
- The public at large feels left out of the planning of hydropower development, in particular, in areas with indigenous population;
- Absence of unified criteria of environmental impact assessment for SHP;
- A 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;
- The water rights legal constitution is under modification;
- Normally, SHP development takes place far from the transmission lines, so that the project developers have to invest in the lines as well, which often makes projects unfeasible;
- Because of climate change it is expected that hydropower potential will decrease by 11–22 per cent;
- The central part of Chile has faced a mega-drought from 2010 to the present with mean rainfall deficits of 20–40 per cent;
- Increasing water stress due to climate change.

The following points summarize the main enablers for SHP development that have been identified:

- Due to its geography and climate, Chile has a high hydropower potential, a large part of which remains undeveloped;
- Aiming to reduce greenhouse gas emissions, several

state initiatives and policies have been or will be generated to boost renewable energy generation, including SHP. There is an ongoing decarbonization plan that has as goal to completely remove coal-fired thermal power plants from the energy mix by 2040. This policy could pose an opportunity for SHP because the shutdown of thermal power plants entails a reduction in baseload production, which could be provided for by SHP.

REFERENCES

1. United Nations Department of Economic and Social Affairs (2020). *Population Dynamics*. Available at https://population.un.org/wpp/Download/Standard/Population/ (Accessed 1 January 2020).
2. National Statistics Institute (INE) (2017). *National Statistical Compendium*. [not available online]
3. World Atlas (2017). *Tallest Mountains in Chile*. Available at https://www.worldatlas.com/articles/tallest-mountains-in-chile.html (Accessed 11 November 2021).
4. Climates to Travel (n.d.). *Climates - Chile*. Available at https://www.climatestotravel.com/climate/chile#south (Accessed 11 November 2021).
5. Ministry of Environment (2017). *National action plan on climate change 2017-2022*. Available at https://mma.gob.cl/wp-content/uploads/2018/06/PANCCv3-19-10-baja.pdf (Accessed 22 August 2021).
6. World Atlas (2018). *The Longest Rivers of Chile*. Available at https://www.worldatlas.com/articles/the-longest-rivers-of-chile.html. (Accessed 11 November 2021).
7. National Commission of Energy (CNE) (2020). *Generation Installed Capacity*. Available at https://www.cne.cl/estadisticas/electricidad/ (Accessed 14 January 2021).
8. National Commission of Energy (CNE) (2020). *Gross generation in SEN 2020*. Available at https://www.cne.cl/estadisticas/electricidad/ (Accessed 14 January 2021).
9. 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. [not available online]
10. National Commission of Energy (CNE) (2021). *Energy Statistics*. Available at https://www.cne.cl/normativas/electrica/consulta-publica/electricidad/ (Accessed 11 November 2021).
11. Ministry of Economy, Development and Reconstruction (2018). *Standard specifications RPTD N°01: Rated voltage and frequency*. [not available online]
12. Ministry of Economy, Development and Reconstruction (2018). *Decree with Force of Law 4: General Law of Electrical Services*. s.l.: Ley Chile, 2017.
13. Ministry of Mining (2014). *Decree 2224*. [not available online]
14. Ministry of Economy, Development and Reconstruction (2016). *Law 18,410*. [not available online]
15. Ministry of Energy (2017). *Law 20,936*. [not available online]
16. Ministry of Economy, Development and Reconstruction (2018). *Decree 44*. [not available online]
17. General Ministry of The Presidency (2012). *Law 20,417*. Available at https://www.bcn.cl/leychile/navegar?idNorma=1010459&idVersion=20 (Accessed 24 November 2022).
18. National Commission of Energy (CNE) (2020). *Marginal Cost*. Available at http://energiaabierta.cl/visualizaciones/costo-marginal-promedio-diario/ (Accessed 14 January 2021).
19. Ministry of Economy, Development and Reconstruction (2013). *Law 20.257*. [not available online]
20. Ministry of Energy (2017). *4eChile Mini/Micro Hydraulic Power Plant Technology Sheet*. Renewable Energy and Energy Efficiency Program. Available at https://www.4echile.cl/4echile/wp-content/uploads/2017/09/fichas-tecnologicas-micro-central-hidraulica.pdf (Accessed 8 October 2018).
21. National Electric Coordinator (CEN)(n.d.). *Database of Installations in operation for generating units*. Available at https://infotecnica.coordinador.cl/instalaciones/unidades-generadoras (Accessed 14 January 2021).
22. Ministry of Energy, General Directorate of Water & University of Chile (2015). *Hydroelectric Potential of Chile: 2014 update*. Available at http://walker.dgf.uchile.cl/Explorador/DAANC/ (Accessed 2 August 2021).
23. Association of Small and Medium Hydropower Plants (APEMEC) (2020). *Monthly Brochure - July 2020*. Available at http://www.apemec.cl/boletin/ (Accessed 22 August 2021).
24. UNIDO, ICSHP (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
25. UNIDO, ICSHP (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
26. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
27. National Commission of Energy (CNE) (2016). *Technical standard of connection and operation of PMGD in medium voltage installations*. [not available online]
28. Ministry of Energy (2015). *Basis for territorial planning in future hydropower development*. Available at https://biblioteca.digital.gob.cl/handle/123456789/529 (Accessed 01 August 2021).
29. National Commission of Energy and National Commission of Irrigation (2007). *Hydropower potential estimation associated to existing or project irrigation works*. [not available online].
30. Environmental Evaluation System (n.d.). *Projects Database*. Available at https://www.sea.gob.cl/ (Accessed 1 January 2021).
31. Ministry of Energy (2016). *Energy 2050 Energy Policy of Chile - documents of the process*. Available at http://www.energia2050.cl/es/documentos/ (Accessed 8 October 2018).
32. Ministry of Energy (2016). *Roadmap 2050, Towards a sus-*

tainable and inclusive energy for Chile. Available at http://www.energia2050.cl/wp-content/uploads/2016/07/Hoja-de-Ruta-2050.pdf (Accessed 8 October 2018).

33. Ministry of Energy (2016). *Energy 2050 - Energy Policy of Chile*. Available at http://www.energia2050.cl/wp-content/uploads/2016/07/Politica-Energetica-Nacional.pdf (Accessed 8 October 2018).
34. Ministry of Energy (2016). *Energetic Route 2018 - 2022, Leading the modernization with citizen*. Available at www.energia.gob.cl (Accessed 3 October 2018).
35. National Congress (2011). *Reform of the Water Code*. Available at http://www.senado.cl/appsenado/templates/tramitacion/index.php?boletin_ini=7543-12 (Accessed 3 October 2018).
36. National Commission of Energy (2020). *Report of costs of generation technologies*. Available at https://www.cne.cl/wp-content/uploads/2020/03/ICTG-Marzo-2020.pdf (Accessed 22 August 2022).
37. Ministry of Energy (2014). *Renewable energy in Chile. Wind, Solar and hydroelectric potential from Arica to Chiloé*. Available at www.minenergia.cl/archivos_bajar/Estudios/Potencial_ER_en_Chile_AC.pdf (Accessed 22 August 2021).
38. Production Development Corporation (CORFO) (2020). *CORFO creates a green credit to boost investment in renewable energy, energy efficiency and circular economy projects*. Available at https://www.corfo.cl/sites/Satellite?c=C_NoticiaNacional&cid=1476726069516&d=Touch&pagename=CorfoPortalPublico%2FC_NoticiaNacional%2FcorfoDetalleNoticiaNacionalWeb (Accessed 1 February 2021).
39. Electricidad (2020). *Virtual Dam of AES Gener: the world first project of batteries in a hydroelectric plant*. Available at https://www.revistaei.cl/reportajes/virtual-dam-de-aes-gener-el-primer-proyecto-mundial-de-baterias-en-hidroelectrica/ (Accessed 30 January 2021).

Colombia

Alexandra Planas Marti, Inter-American Development Bank

KEY FACTS

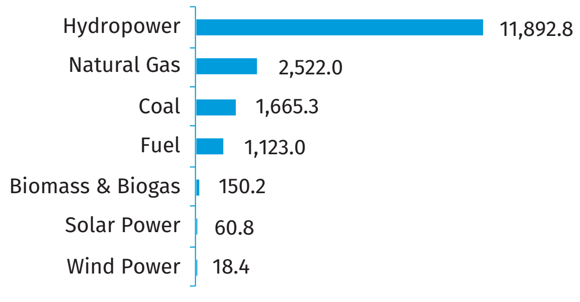
Population	48,258,494 (2018)[1]
Area	1,141,748 km^2 [2]
Topography	Colombia is situated in the northern part of South America and has a coastline on both the Pacific Ocean and the Caribbean Sea. The Andes Mountain Range crosses the western and central parts of the country, and the highest point in the country is the Sierra Nevada de Santa Marta (5,775 metres).[2] On the contrary, the eastern region of the country is characterized by extensive plains.
Climate	The climate of Colombia is shaped by its varied topography. The average temperature in the Pacific region is 26-28 °C, in the Orinoco region 24-28 °C, in the Amazonian 24-26 °C region and over 26 °C in the Caribbean region. At the same time, the average temperature in the Andean region varies between 8 °C and 24 °C.[3,4]
Climate Change	Even though Colombia emits 0.46 per cent of global greenhouse gas emissions, the country is highly vulnerable to certain effects of climate change such as floods, changes in water resources and rain patterns, desertification of productive soils and health issues like malaria and dengue fever.[5]
Rain Pattern	The highest average precipitation level is found in the Pacific region, where most municipalities receive between 4,000 mm and 9,000 mm of rainfall. However, some municipalities can receive more than 11,000 mm.6 High average precipitation can also be found in the Amazonian region, between 3,000 mm and 4,000 mm.6 The Orinoco and Caribbean regions have varied rain patterns, receiving between 1,000 mm and 4,000 mm of rainfall. Meanwhile, most municipalities in the Caribbean region receive less than 1,500 mm of rainfall per year.6 The Caribbean, Andean and Orinoco regions experience dry seasons from the last months of the year until March, when the wet season begins. On the other hand, the Pacific and Amazonian regions receive precipitation throughout the year.[7]
Hydrology	The hydrology of Colombia is characterized by the presence of wide and fast-flowing rivers (Magdalena, Causa, Amazonas, Putumayo, Caquetá and Guaviare, among others). This explains the country's hydropower potential as well as its vulnerability to climate change effects.

ELECTRICITY SECTOR OVERVIEW

As of December 2020, Colombia had an installed capacity of 17,432.4 MW (Figure 1).[8] The country's electricity mix is characterized by a high reliance on hydropower, which in 2020 accounted for 68 per cent of total capacity. On the other hand, fossil fuel-powered plants accounted for approximately 30 per cent. Electricity generation in 2020 amounted to 69,323.5 GWh (Figure 2).[9] Approximately 73 per cent of the total originated from renewable energy sources, including almost 72 per cent from hydropower.

Electricity demand in 2020 was also lower than in 2019. The National Government and local authorities established total and partial lockdowns throughout 2020 due to the COVID-19 pandemic. This situation affected electricity consumption by industrial and commercial users, which resulted in a contraction of electricity demand — especially, between April and September 2020.[11]

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

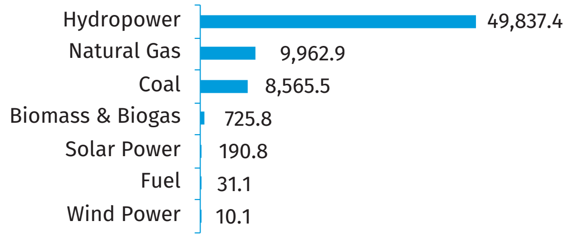


Source: XM[8]

Even though most of the electricity in 2020 was generated from hydropower, that year this source represented a smaller share of total electricity generation in comparison to 2019.[10] This was a result of declined water levels in reservoirs due to hydroclimatic conditions. Thus, between January and April 2020, the water level in reservoirs descended from 54.2

per cent to 31.8 per cent of capacity; and only by July were the reservoirs able to return to 2019 levels. The remaining electricity was generated mostly by coal and natural gas power plants.[10]

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

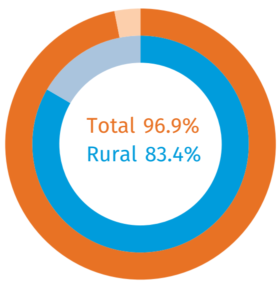


Source XM[9]

An important characteristic of the Colombian electricity sector is its integration with other countries. During 2020, Colombia exported 8.3 GWh to, and imported 42.7 GWh from, Ecuador.[12] In December 2020, the Colombian Ministry of Mines and Energy accepted the *pro tempore* presidency of the Andean Interconnection System (SINEA), a regional effort to integrate the electricity infrastructure, regulation and markets of Colombia, Ecuador, Peru, Bolivia and Chile. The country is also working on a future interconnection with Panama, which will allow the integration of the Andean and Central America markets.

In terms of electricity coverage, according to the Inter-American Development Bank's Energy Hub, the country ensured energy access to 96.9 per cent of its population in 2018 and 83.4 per cent of the rural population in 2017.[13,14] Of the population without electricity access, 97.2 per cent live in rural areas (approximately 471,000 people).[13]

Figure 3. **Electrification Rate in Colombia (%)**



Source: IADB,[13] RAP-E[14]

Note: Rural electrification data for 2017; total electrification data for 2018.

The National Government has set a goal of providing electricity to 100,000 additional households between 2018 and 2022 and, following the commitments under the Sustainable Development Goals, universal access is expected to be achieved by 2030.[15,16] This is essential for improving living conditions in the non-interconnected zones, which represent 52 per cent of the country's territory and where only 7.26 per cent of the installed capacity was renewable (21.29 MW) as of December 2020.[17,18]

The characteristics of the electricity sector of Colombia were defined in 1994 by the public utilities law (Law 142/1994) and the electricity law (Law 143/1994).[19,20] According to those laws, the electricity generation and commercialization activities are open to competition and private participation is encouraged. Therefore, during the past decades these segments have seen an increasing participation of national and foreign companies.

As a result, the main stakeholders of the electricity sector are present in both the public and private sectors. In the public sector, the Ministry of Mines and Energy sets the public policy for the electricity sector; the Energy and Mining Planning Unit (UPME) and the Energy Planning Institute for Non-Interconnected Zones (IPSE) oversee planning; the Energy and Gas Regulatory Commission (CREG) regulates the electricity market; and the Superintendency of Public Utilities enforces the said regulations. Moreover, some of the largest Colombian public and private companies belong to the energy sector, such as Enel, Empresas Públicas de Medellín, Enel Colombia, Interconexión Eléctrica (ISA) and Grupo de Energía de Bogotá. Most of these companies integrate generation, transmission, distribution or commercialization activities since the current regulations have increased flexibility in vertical integration rules.[21]

Electricity tariffs are determined by the CREG for each regional distributor, following a formula determined by CREG Resolution 91/2007. Between 2015 and 2019, average monthly prices varied between 0.07 USD/kWh and 0.12 USD/kWh, depending on the region. During 2019, the departments of Nariño and Casanare paid the highest tariffs, while Arauca and Putumayo paid the lowest tariffs.[22]

SMALL HYDROPOWER SECTOR OVERVIEW

Law 697/2001 first established a definition of small hydropower (SHP) resources (*pequeños aprovechamientos hidroenergéticos*), which limited the notion of SHP to power plants under 10 MW. Afterwards, Law 1715/2014 broadened the definition and established that SHP includes all small-scale hydropower plants of up to 20 MW.[23,24] Including power plants under 20 MW is congruent with the Colombian electric market regulation. Regardless of its source, all plants under 20 MW are considered minor plants (*plantas menores*). In Colombia, minor plants are neither subject to Central Dispatch nor used for grid balancing. Following the Colombian Hydropower Potential Atlas, adopted by the UPME, SHP can be classified into further categories of pico-, micro-, mini- and small hydropower (Table 1).[25]

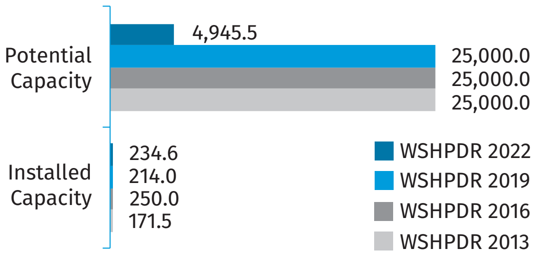
Table 1. **Classification of Small Hydropower in Colombia**

Category	*Installed capacity*
Pico	0.5 kW – 5 kW
Micro	5 kW – 50 kW
Mini	50 kW – 500 kW
Small	500 kW – 20 MW

Source: UPME[25]

As of September 2020, Colombia had 234.64 MW of installed SHP capacity for plants up to 10 MW.[26] For plants under 20 MW, the installed capacity was 900.79 MW as of December 2020.[27] In comparison to the *World Small Hydropower Development Report (WSHPDR) 2019*, the country increased by 20.64 MW its installed capacity in plants up to 10 MW.[28] The change between the data reported in the *WSHPDR 2019* and the *WSHPDR 2022* is justified by access to more accurate data (Figure 4) and new SHP capacity additions (Table 2). The potential capacity for SHP up to 10 MW is estimated at 4,946 MW, indicating a drastic change from an estimated 25,000 MW according to the *WSHPDR 2019*, which is also due to new and more accurate data.[25]

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



Source: UPME,[25] WSHPDR 2019,[28] *WSHPDR 2013*,[29] *WSHPDR 2016*[30]

Note: Data for SHP up to 10 MW.

According to the Public Registry of Generation Projects (administered by UPME), as of November 2020, 43 additional hydropower projects between 1 MW and 10 MW, representing a combined capacity of 254 MW, had been submitted for approval.[31] Of these, 23 are in the Antioquia department, 8 in the Caldas department, 3 in Tolima, 3 in Risaralda, 3 in Calle del Cauca, 2 in Norte de Santander and 1 in Cauca. These projects represent 28.7 per cent of the 887 MW of new small-scale projects in the Registry that are awaiting approval and 7.3 per cent of the 3,471 MW that represents all hydropower projects in the Registry.[31]

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

Name	*Location*	*Capacity (MW)*	*Operator*	*Launch year*
PCH La Libertad	Toca, Boyacá	1.20	EMPRESA GENERADORA Y COMERCIALIZADORA DE ENERGIA ELECTRICA DE COLOMBIA S.A. E.S.P.	2020
Urrao	Urrao, Antioquia	1.03	ESPACIO PRODUCTIVO S.A.S. E.S.P.	2020
Prado IV	Prado, Tolima	5.00	CELSIA COLOMBIA S.A. E.S.P.	2019
Nima	Cali, Valle del Cauca	6.70	CELSIA COLOMBIA S.A. E.S.P.	2019
Rio Cali	Cali, Valle de Cauca	1.80	CELSIA COLOMBIA S.A. E.S.P.	2019
El Cocuyo	Versalles, Valle des Cauca	0.70	CELSIA COLOMBIA S.A. E.S.P.	2019
Cantayus	Cisneros, Antioquia	4.32	GENERADORA CANTAYÚS S.A.S E.S.P	2019
Hidrobarrancas	Dabeiba, Antioquia	4.70	MARERSA JEK COLOMBIA SAS ESP	2019
Amalfi	Amalfi, Antioquia	0.81	HZ ENERGY S.A.S. E.S.P	2019
Autg Cementos Del Nare	Pto Nare, Antioquia	9.00	EMPRESAS PUBLICAS DE MEDELLIN E.S.P.	2019
Mulatos Ii	Bolombolo, Antioquia	7.34	RENOVATIO TRADING AMERICAS S.A.S. E.S.P	2019

Source: UPME[26]

Furthermore, according to UPME's Public Registry, as of November 2020, 19 new hydropower projects between 10 MW and 20 MW, representing a total of 321 MW, had been submitted for approval. Of these, 8 are in Antioquia, 2 in Tolima, 2 in Boyacá, 2 in Cauca, 1 in Norte de Santander, 1 in Risaralda, 1 in Quindío, 1 in Arauca and 1 in Cundinamarca. These projects account for 32.5 per cent of the 988 MW of all projects of the same size in the Registry and 9.2 per cent of the 3,471 MW representing all hydropower projects in the Registry.[31]

Finally, based on a 2015 study by Pontificia Universidad Javeriana, the 2015 Hydropower Potential Atlas provides an estimate of the total run-of-river hydropower potential in Colombia by region and plant size based on turbine flow, hydraulic drop and efficiency. The country's total theoretical SHP potential is estimated at 4,946 MW (Table 3).[32] Thus, approximately 4.7 per cent of identified SHP potential has been developed so far. There is currently no available data regarding SHP sites available for development or refurbishment.

Table 3. **Theoretical Small Hydropower Potential in Colombia (kW)**

Region	*Pico*	*Micro*	*Mini*	*Small*
Amazonian Region	285	2,799	26,948	903,311
Caribbean Region	210	1,935	16,843	436,476
Andean Region*	514	5,229	47,567	1,646,204
Orinoco Region	360	3,599	35,789	1,230,958
Pacific Region	165	1,647	15,984	568,657
Total	**1,553**	**15,209**	**143,132**	**4,785,606**

Source: UPME[32]

Note: *The Andean Region is referred to in the 2015 Hydropower Potential Atlas as 'Magdalena & Cauca' due to the two main rivers that cross this region.

RENEWABLE ENERGY POLICY

The promotion of renewable energy was first outlined in Law 697/2001 and recently developed by Law 1715/2014.[23,24] According to the latter, the promotion of non-conventional renewable energy is a matter of 'public utility and social interest' due to its connection to energy security, competitiveness and environmental sustainability. This status grants non-conventional renewable energy a preferential standing in several legal topics, such as urbanism, environment, administrative and procurement matters.

The most relevant dispositions contained in Law 1715/2014 relate to fiscal incentives for non-conventional renewable projects, the promotion of small-scale projects such as self-generation and distributed generation and the replacement of diesel generation in non-interconnected zones.[24] Nonetheless, most of the legal and regulatory development of Law 1715/2014 has focused on solar and wind power projects. For instance, additional fiscal incentives have been introduced to specific components of these technologies.

In 2019, the National Government committed to increasing the non-conventional renewable energy installed capacity to 1,500 MW by 2022.[33] To meet this goal, a renewable energy portfolio standard was created by Law 1955/2019 and several renewable energy auctions have been and will be organized by the Government.[34] The expected outcome of these policies is the increase of non-conventional renewable energy installed capacity to over 2,250 MW by 2022.[34]

Furthermore, Colombia is committed to transforming its energy sector to comply with its commitment under the Paris Agreement. According to its initial Nationally Determined Contribution (NDC), the country committed to reduce by 20 per cent its greenhouse gas emissions by 2030.[35] This target could increase to 30 per cent in case international cooperation is ensured. Recently, the country updated its NDC and increased its mitigation ambition by establishing a new commitment of reducing its greenhouse gas emissions by 51 per cent by 2030.[36]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

According to Law 1715/2014, SHP is considered non-conventional renewable energy. Hence, the tax benefits created for its promotion are applicable to such projects as well, which are the main incentives for these projects currently.[24] As previously stated, the said law contains a definition of SHP, which includes all small-scale hydropower plants. This is a wider definition in comparison to what was stated in Law 697/2001, which circumscribed SHP to power plants under 10 MW.[23]

Moreover, due its classification as a non-conventional renewable energy source, SHP could be financed through mechanisms applicable to this category of technologies. The financial sector's interest in renewable energy is increasing and the appearance of future financial instruments is expected in the short term. Moreover, the Government has a fund devoted to investing in renewable energy (Non-Conventional Energies and Energy Efficiency Fund, or FENOGE) whose resources could eventually be used to finance SHP projects.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

The considerable hydropower potential of Colombia might become a liability due to the climate crisis. Due to the country's exposure to the crisis, negative effects are foreseen in different sectors and regions. Regarding water resources, it is expected that more than 50 per cent of the national territory will be affected by changes in the hydrologic systems.[33] These changes will vary depending on the region: some parts of the country will experience a reduction in precipitation, while others will see an increase. Overall, given the large share of hydropower in national electricity generation, this might eventually affect energy security of the country.[37]

For this reason, as a mitigation measure against the effects of the climate crisis, the Colombian energy policy is mainly focusing on promoting solar and wind power energy, as well as storage systems. This might dissuade investment in hydropower projects in the medium and long run.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The previous edition of the *WSHPDR*, identified several barriers to SHP development in Colombia, some of which are considered to persist over time.[28] The following points summarize the main barriers that have been identified:

- Substantial climatic variations may affect the reliability of hydropower;
- Efforts to reduce dependence on hydropower to increase energy security due to the mentioned climate variations;

- Preference of solar and wind power over SHP, even in non-interconnected zones;
- Deficit in research and development investments for SHP projects;
- Institutional fragility can discourage investment in SHP in non-interconnected zones;
- Lack of awareness or support on the part of the communities, especially in non-interconnected zones;
- Overvaluation of land in rural zones by landowners.

The key enablers for SHP development in Colombia are the favourable geographic and hydrological conditions.

REFERENCES

1. National Administrative Department of Statistics (DANE) (2018). *Censo Nacional de Población y Vivienda 2018*. Available at https://www.dane.gov.co/index.php/estadisticas-por-tema/demografia-y-poblacion/censo-nacional-de-poblacion-y-vivenda-2018/cuantos-somos (Accessed 22 February 2021).
2. Ministry of Environment (2015). *Colombia, country of mountains*. Available at https://www.minambiente.gov.co/index.php/noticias-minambiente/2170-colombia-pais-de-montanas#:~:text=La%20monta%C3%B1a%20m%C3%A1s%20alta%20de,la%20superficie%20continental%20del%20pa%C3%ADs. (Accessed 22 February 2021).
3. Institute of Hydrology, Meteorology and Environmental Studies (2018). *Atlas Climatológico de Colombia*. Available at http://documentacion.ideam.gov.co/openbiblio/bvirtual/023777/CLIMA.pdf (Accessed 22 February 2021).
4. Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) (2020). *Temperatura Media Anual*. Available at http://atlas.ideam.gov.co/basefiles/Temp_Med_Anual.pdf (Accessed 22 February 2021).
5. Government of Colombia (2015). *Contribución Prevista y Determinada a Nivel Nacional*. Available at https://www.minambiente.gov.co/images/cambioclimatico/pdf/colombia_hacia_la_COP21/iNDC_espanol.pdf (Accessed 22 February 2021).
6. Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) (2020). *Seguimiento de la Precipitación*. Available at http://www.ideam.gov.co/web/tiempo-y-clima/precipitacion-mensual-por-ano (Accessed 22 February 2021).
7. Institute of Hydrology, Meteorology and Environmental Studies (2020). *Inicio de la primera temporada de lluvias del año 2020 en Colombia*. Available at http://www.ideam.gov.co/documents/10182/0/comunicado+especial+N.7/4d5e462f-fd50-41f8-8dbd-8a3f72c714f8?version=1.0 (Accessed 22 February 2021).
8. XM (2020). *Capacidad Efectiva Neta por Combustible - Portal BI*. Available at http://portalbissrs.xm.com.co/oferta/Paginas/Capacidad/capefenetporcom.aspx (Accessed 22 February 2021).
9. XM (2020). *Indicadores - Generación SIN (GWh). Resolución: Mensual*. Available at https://www.xm.com.co/Paginas/Indicadores/Oferta/Indicador-generacion-sin.aspx (Accessed 22 February 2021).
10. XM (2020). *Indicadores – Aportes Hídricos. Resolución: Mensual*. Available at https://www.xm.com.co/Paginas/Indicadores/Oferta/Indicador-aportes-hidricos.aspx (Accessed 22 February 2021).
11. XM (2020). *Indicadores – Demanda y Crecimiento de la Demanda*. Available at https://www.xm.com.co/Paginas/Indicadores/Demanda/Indicador-demanda-crecimiento-demanda.aspx (Accessed 22 February 2021).
12. XM (2020). *Indicadores – Intercambios Internacionales*. Available at https://www.xm.com.co/Paginas/Indicadores/Intercambios%20internacionales/Indicador-importaciones.aspx (Accessed 22 February 2021).
13. Inter-American Development Bank (2018). *Acceso al servicio de electricidad*. Available at https://hubenergia.org/es/indicators/acceso-al-servicio-de-electricidad (Accessed 22 February 2021).
14. Región Administrativa y de Planeación Especial (RAP-E) (2020). *ESTADO DE LA COBERTURA ELECTRICA Y LAS ZONAS NO INTERCONECTADAS EN LA REGIÓN CENTRAL*. Available at https://regioncentralrape.gov.co/wp-content/uploads/2020/05/Cpt0l7-ESTADO-DE-LA-COBERTURA-ELECTRICA-Y-LAS-ZONAS-NO-INTERCONECTADAS-EN-LA-REGIO%C-C%81N-CENTRAL.pdf (Accessed 22 February 2021).
15. National Planning Department (2018). *Bases del Plan Nacional de Desarrollo 2018-2022*. Available at https://www.dnp.gov.co/Plan-Nacional-de-Desarrollo/Paginas/Bases-del-Plan-Nacional-de-Desarrollo-2018-2022.aspx (Accessed 22 February 2021).
16. National Council for Economic and Social Policy (2018). *Documento CONPES 3918: Estrategia para la Implementaación de los Objetivos de Desarrollo Sostenible (ODS) en Colombia*. Available at https://colaboracion.dnp.gov.co/CDT/Conpes/Econ%C3%B3micos/3918.pdf (Accessed 22 February 2021).
17. Superintendence of Public Utilities (2017). *Zonas No Interconectadas: Diagnóstico de la Prestación del Servicio de Energía Eléctrica*. Available at https://www.superservicios.gov.co/sites/default/archivos/SSPD%20Publicaciones/Publicaciones/2018/Sep/diagnosticozni-superservicios-oct-2017.pdf (Accessed 22 February 2021).
18. Data provided by the Institute of Energy Planning in Non-Interconnected Zones (IPSE).
19. Law 142 of 1994 [Ley 142 de 1994 Nivel Nacional, Diario Oficial 41.433 del 11 de julio de 1994]. Available at https://www.alcaldiabogota.gov.co/sisjur/normas/Norma1.jsp?i=2752 (Accessed 22 February 2021).
20. Law 143 of 1994 [Ley 143 de 1994 Nivel Nacional, Diario Oficial No. 41.434, de 12 de julio de 1994]. Available at https://www.minenergia.gov.co/documents/10180/667537/Ley_143_1994.pdf (Accessed 22 February 2021).
21. Ley 1955 de 2019 por el cual se expide el Plan Nacional de Desarrollo 2018-2022. "Pacto por Colombia, Pacto por la Equidad". DIARIO OFICIAL. Año CLV No. 51.120. 28, AGOSTO, 2019. El Congreso de Colombia, 25 mayo 2019. Available at http://www.suin-juriscol.gov.co/viewDocument.asp?ruta=Leyes/30036488#:~:text=El%20Plan%20establece%20las%20

bases,fortalecimiento%20de%20la%20Rama%20Judicial (Accessed 22 February 2021).
22. Markup Consultores (2020). *Precios mercado eléctrico minorista dirigido a usuarios no regulados (2015-2019).* Available at http://www.markup.com.co (Accessed 22 February 2021).
23. Law 697 of 2001 [Ley 697 de 2001 Nivel Nacional, Diario Oficial No. 44573 del 5 de octubre de 2001]. Available at https://www.alcaldiabogota.gov.co/sisjur/normas/Norma1.jsp?i=4449 (Accessed 22 February 2021).
24. *Ley 1715/2014 Por Media de la Cual de Regula la Integración de las Energías Renovables no convencionales al sistema energético nacional.* Art. 5. El Congreso de Colombia, 14 May 2014. Available at https://www.upme.gov.co/Normatividad/Nacional/2014/LEY_1715_2014.pdf (Accessed 22 February 2021).
25. Energy and Mining Planning Unit (2015). *Atlas de Potencial Hidroenergético.* Available at https://www1.upme.gov.co/Paginas/Primer-Atlas-hidroenergetico-revela-gran-potencial-en-Colombia.aspx (Accessed 22 February 2021).
26. Energy and Mining Planning Unit (2020). *Capacidad Efectiva de De Generación (SIN).* Available at http://www.upme.gov.co/Reports/Default.aspx?ReportPath=%2fSIEL+UPME%2fGeneraci%c3%b3n%2fCapacidad+Efectiva+de+Generaci%c3%b3n+(SIN) (Accessed 22 February 2021).
27. XM (2020). *Capacidad Efectiva Neta por Combustible - Portal BI.* Available at http://portalbissrs.xm.com.co/oferta/Paginas/Capacidad/capefenetporcom.aspx (Accessed 22 February 2021).
28. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
29. UNIDO, ICSHP (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
30. UNIDO, ICSHP (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
31. Energy and Mining Planning Unit (2020). *Informe de Registro de Proyectos de Generación de Electricidad.* Available at https://app.powerbi.com/view?r=eyJrIjoiODRjNWM2NmEtZDI5MC00OGJhLWFmMTItYmU3NTNiMDE4MTM2IiwidCI6IjUxYzFhOGQwLTMyYmQtNDZlYi05YmRlLTkxZTZlNGU3MDRmZCJ9 (Accessed 21 February 2021).
32. Energy and Mining Planning Unit (2015). *Atlas de Potencial Hidroenergético.* Available at https://www1.upme.gov.co/Paginas/Primer-Atlas-hidroenergetico-revela-gran-potencial-en-Colombia.aspx (Accessed 22 February 2021).
33. National Planning Department (2018). *Bases del Plan Nacional de Desarrollo 2018-2022.* Available at https://www.dnp.gov.co/Plan-Nacional-de-Desarrollo/Paginas/Bases-del-Plan-Nacional-de-Desarrollo-2018-2022.aspx (Accessed 22 February 2021).
34. Inter-American Development Bank (2019). *El sol y el viento transformarán la matriz energética de Colombia. Energía para el Futuro Blog.* Available at https://blogs.iadb.org/energia/es/el-sol-y-el-viento-transformaran-la-matriz-energetica-de-colombia/ (Accessed 22 February 2021).
35. Government of Colombia (2015). *Contribución Prevista y Determinada a Nivel Nacional.* Available at https://www.minambiente.gov.co/images/cambioclimatico/pdf/colombia_hacia_la_COP21/iNDC_espanol.pdf (Accessed 22 February 2021).
36. Ministry of Environment (2020). *Colombia reducirá en un 51% sus emisiones de gases efecto invernadero para el año 2030.* Available at https://www.minambiente.gov.co/index.php/noticias/4877-colombia-reducira-en-un-51-sus-emisiones-de-gases-efecto-invernadero-para-el-ano-2030 (Accessed 22 February 2021).
37. Ministry of Environment (n.d.). *Impacto del Cambio Climático en Colombia.* Available at https://www.minambiente.gov.co/index.php/component/content/article/457-plantilla-cambio-climatico-13 (Accessed 22 February 2021).

Ecuador

Poullette Faraon Chaul Corona, Independent Consultant

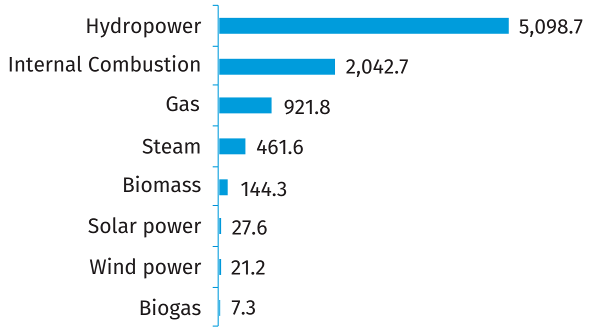
KEY FACTS

Population	17,510,643 (2020)[1]
Area	256,370 km2 [2]
Topography	Ecuador is located at the north-west part of South America, with Colombia to the north, Peru to the east and south and the Pacific Ocean to the west, where it holds an insular region, the Galapagos Islands. From north to south, the territory is crossed by the Andes Mountains (the Sierra region), which brings a diverse topography. At both sides of the Andes lie lowlands with a slightly rugged topography —the coastal region to the west and the Amazon plain to the east. The highest point of the country is Mount Chimborazo, at 6,267 metres above sea level. The country's capital, Quito, lies at an elevation of 2,850 metres.[3,4]
Climate	Given its location on the equator, Ecuador mostly has a humid tropical climate with two seasons: winter (humid) and summer (dry). The climate in the country is highly influenced by its topography, with temperature varying between 0 °C and 26 °C throughout the year. The temperatures depend on the region and elevation, with a tight inverse relationship between altitude and temperatures. The average temperature in the Galapagos Islands is 23 °C, in the coastal and Amazonian regions between 24 °C and 25 °C and in the Sierra region between 8 °C and 20 °C. The average annual temperature variation in the country is approximately 3 °C, nonetheless, the daily variations might fluctuate from 10 °C in low and coastal areas to 20 °C in the Andes Mountains.[5]
Climate Change	Studies have shown that climate change has impacted Ecuador (between 1960 and 2006) with an increase in anomalous climate events, mainly in the coastal and the Amazonian regions. There has been an increase in temperatures, their variations and rainfall, mainly in the coastal and Sierra regions. A 2021 study showed that in the last 20 years, in some areas of the coastal region, there has been an increase in rainfall, but the change in temperature has not been relevant. Regarding the Sierra and Amazonian regions, a 2021 study that analyzed the 1980-2019 period showed that, in most areas, temperature and rainfall have a decreasing tendency, however, further research is required. Hydrological systems are particularly vulnerable to changes in rainfall or droughts caused by climate change. Some areas of the coastal region are more prone to floods and droughts (Guayas and Jubones Rivers). In the Sierra region, there is more risk of landslides and erosion, and the Amazonian region might experience high risk floods (areas close to Peru). In Ecuador, a 2 °C increase in temperature is expected towards the end of the century, which could be higher in the Amazonian Region and the Galapagos islands.[6,7]
Rain Pattern	The average annual rainfall in Ecuador is 2,249 mm. High rainfall is present in the Amazonian and northern coastal regions, while it is low in the centre and southern coastal region. The coastal region presents an average annual rainfall of 400–3,000 mm, with 70–95 per cent of annual precipitation taking place between December and May. The Sierra region receives 600–3,000 mm of rainfall, with the highest precipitation in February–May and October–December. The Amazonian region receives 2,500–5,000 mm, with constant precipitation throughout the year.[8]
Hydrology	Total runoff rainwater averages 432,000 hm^3, which gives a specific annual runoff of 1,600 mm/year, exceeding the world average (of 33 mm/year). There are two main basins that absorb rainfall through a concentrated hydrographic network: the Amazon River basin, which generates approximately 70 per cent of the medium flow, and the Pacific basin, responsible for the generation of 30 per cent of the medium flow. Ecuador has 376,020 hm3 of annual water resources (361,750 hm3 surface and 56,560 hm3 underground, of which only 14,270 hm3 account for a non-repetitive volume). The average annual volume is 70,046 hm3 for the coastal region, 59,725 hm3 for the Sierra region and 246,246 hm3 for the Amazonian region. The country holds approximately 1,275 rivers and over 100 water catchment areas. Most of the rivers in Ecuador are abundant and navigable. Originated from the mountains, they drain to either the Pacific Ocean or the Amazon River.[9]

ELECTRICITY SECTOR OVERVIEW

In 2020, the total installed capacity in Ecuador was of 8,712.3 MW. By May 2021, it reached 8,725.2 MW, with renewable sources accounting for almost 61 per cent of the total capacity (hydropower, wind power, solar power, biomass and biogas) and non-renewable sources accounting for 39 per cent (internal combustion motors, gas and steam) (Figure 1).[10] The two main hydropower plants are Coca Codo Sinclair (1,500 MW), which supplies 25 per cent of the country's electricity demand, and Paute Molino (1,100 MW), which supplies 19 per cent of the demand.[11] In 2020, the installed capacity of isolated systems reached 1,372 MW, mainly in the regions of Orellana (57 per cent of the capacity) and Sucumbíos (30 per cent).[12] In addition, Ecuador holds 650 MW of installed capacity for electricity imports from Colombia (540 MW) and Peru (110 MW). Renewable energy capacity increased from 2,338.2 MW in 2011 to 5,299.1 MW in 2020, mainly due to new hydropower development. The total hydropower installed capacity went from 2,234.4 in 2011 MW to 5,098.8 MW in 2020.[13] Hence, between 2010 and 2020, renewable energy capacity more than doubled, mainly due to growth in hydropower.[14]

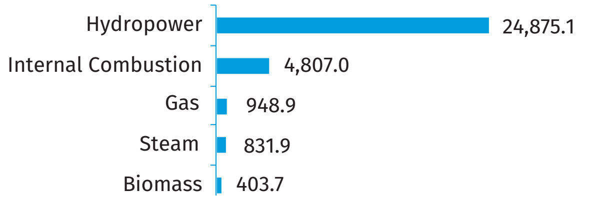
Figure 1. **Installed Electricity Capacity by Source in Ecuador in 2021 (MW)**



Source: ARCONEL[10]

National annual electricity generation reached 31,248 GWh in 2020.[12] In the period of September 2020–August 2021, electricity generation totalled 32,016 GWh (Figure 2).[10] Renewable sources (hydropower, wind power, solar power, biomass and biogas) accounted for 79 per cent of total generation, mainly through hydropower, which represented 78 per cent of the total.[10] Non-renewable sources corresponded to slightly more than 20 per cent of total electricity generation, mainly through internal combustion motors, which represented approximately 15 per cent of total generation.[10] In addition to domestic generation, during the same period, Ecuador also imported 279.7 GWh from Colombia.[10] Ecuador exported a total of 385.0 GWh to Colombia (95 per cent of total exports) and 40.8 GWh to Peru (5 per cent) during the same period.[10] In 2020, the electricity sector experienced 4,417 GWh of losses on transmission and distribution lines.[15]

Figure 2. **Annual Electricity Generation by Source in Ecuador in 2020/2021 (GWh)**



Source: ARCONEL[10]

Note: Data for the period of September 2020–August 2021.

A particularly high electricity demand was observed in Ecuador throughout 2019, having reached a historic record on 8 May (3,949.9 MW), with 91 per cent coverage from hydropower generation.[16] However, the Covid-19 pandemic had an important impact on electricity demand due to a reduction in industrial and commercial activities. By May 2020, demand started to recover again with the implementation of economic reactivation measures by the Government.[17] According to the National Electricity Operator (CENACE), the electricity demand in January–July 2021 increased by 8 per cent in comparison to 2020, due to more dynamic commercial and industrial activities.[18] Overall, between 2009 and 2019, per capita electricity consumption increased 39 per cent, reaching 1,517 kWh.[14]

In Ecuador, the power sector has regulated demand (public services) and unregulated demand (big consumers, auto-consumers and self-generators).[13] Public and private companies, duly authorized by the regulator, can generate electricity but only private ones are authorized for self-consumption. Hence, there are power plants owned by generators, self-generators (that may inject and sell surplus to the grid and distribution with generation companies (that provide public services of electricity and street lightning).[19] In December 2020, Ecuador had 139 power plants, of which 59 were private (25 hydropower, 24 solar power, 5 thermal power, 3 biomass and 2 biogas) and 80 public (40 thermal power, 39 hydropower and 1 wind power).[20] The power system is divided into two sections: the National Interconnected System (SNI), which holds most of the installed capacity, and the isolated systems, not connected to the SNI due to hard access, e.g., the Galapagos Islands and remote areas in the Amazon.[21]

The electricity sector in Ecuador is regulated by the 2008 Constitution, the 2015 Organic Law of the Public Electric Power Service (LOSPEE), its General Regulation issued in 2019, the 2019 Energy Efficiency Law, the Electricity Sector Master Plan (PME) updated every four years (the last updated version is for 2018–2027) and the National Energy Efficiency Plan (PLANEE), updated every two years. The Energy Efficiency Law regulates the National System of Energy Efficiency (SNEE) and promotes the efficient and rational use of energy as well as the service and tariffication of electric charging for vehicles. In 2017, Ecuador also issued the National Energy Efficiency Plan.[22] The electricity sector depends on the

Ministry of Energy and Non-Renewable Natural Resources (MERNNR) for the definition of policies and planning. The regulator is the Agency of Regulation and Control of Energy and Non-Renewable Natural Resources (ARC) and the electricity operator CENACE is in charge of the administration of the national interconnected grid (SNI). The Electrical Corporation of Ecuador (CELEC) is the state-owned integrated electricity company in charge of generation, transmission and import of electricity. In 2020, CELEC held most of the total installed capacity in the country at 6,366.2 MW, of which 70 per cent (4,482.2 MW) was from hydropower.[11] The National Electricity Corporation (CNEL EP) is in charge of electricity distribution and commercialization.

According to the World Bank, total electricity coverage in Ecuador in 2019 reached 100 per cent, both in urban and rural areas.[23] Nonetheless, according to ARC, in 2019, the national electrification rate was of 97 per cent, with 98 per cent expected by 2027.[24,25] Since 1999, Ecuador has a fund for rural electrification (FERUM) to increase electricity coverage in rural and remote areas.

Regulation of electricity tariffs, costs of generation, transmission, distribution and commercialization is handled by the ARC (former Agency for Regulation and Control of Electricity, ARCONEL) created in July 2020 after the merger of different regulation and control agencies. Tariffs are updated yearly observing the principles of solidarity, equity, cost coverage and energy efficiency and vary by the type of consumer (industrial, commercial and services or residential) and voltage level (low, medium, high).[26] For 2021, the total approved cost for generation, transmission and distribution of electricity was 0.09 USD/kWh. The average of differentiated tariffs applied by sector of consumers are: residential 0.10 USD/kWh, commercial 0.10 USD/kWh, industrial 0.08 USD/kWh and others 0.07 USD/kWh.[26]

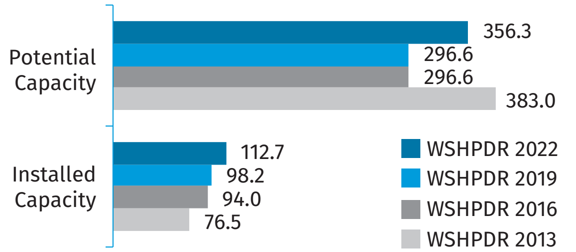
The electricity sector is subsidized, mainly for residential consumers, for example, through the "dignity tariff" and tariff incentives for the Efficient Plan for Induction Cooking and Electric Water Heating (PEC). The former is applied to 1.6 million beneficiaries and offers a reduction in tariffs for elderly people and the disabled, whereas the latter is applied to 14 per cent of households and was implemented in 2014.[11] In the last 10 years, weighted average prices of electricity have decreased from 0.04 USD/kWh in 2011 to 0.03 USD/kWh in 2020. Average prices vary depending on the type of the company: generation (0.03 USD/kWh in 2020), distribution with generation (0.04 USD/kWh in 2020) and self-generation companies (0.05 USD/kWh in 2020). Between 2011 and 2020, the highest prices were for solar power generation (0.04 USD/kWh), given that feed-in tariffs (FITs) have been in place since 2011 in order to incentivize solar power deployment.[13] In 2020, due to the Covid-19 pandemic, compensatory measures were applied, such as subsidies in favour of electricity consumers and the suspension of power cuts as well as of interests and surcharges due to the lack of payment.[27]

SMALL HYDROPOWER SECTOR OVERVIEW

In Ecuador, small hydropower (SHP) plants are considered to have up to 10 MW of capacity. Nonetheless, hydropower plants of slightly higher capacity (even up to 50 MW) are, in practice, sometimes considered as SHP. For the purpose of this chapter, the 10 MW definition will be followed.

In 2020, the installed capacity of SHP in Ecuador was 112.7 MW.[13] Total SHP potential, including developed and undeveloped potential, is estimated at 356.3 MW. The change in installed capacity since the *World Small Hydropower Development Report* (*WSHPDR*) *2019* is due to continued growth of the sector, while the change in potential capacity is due to a new analysis, as identified in the PME (Figure 3).

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



Source: ARCONEL,[11] *WSHPDR 2013*,[28] *WSHPDR 2016*,[29] *WSHPDR 2019*,30 MERNNR[31]

There are 43 SHP plants in Ecuador, including generators (19), self-generators (9) and distribution with generation companies (15), that not all inject to the grid (Table 1). SHP generation (only from generation companies) reached 267.0 GWh in 2020.[13] Two SHP plants started operations in 2020: San José de Minas (6.75 MW) and El Laurel (0.75 MW), which generated a total of 14.7 GWh in 2020.[13]

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

Name	*Location*	*Capacity (MW)*	*Operator*	*Launch year*
San José de Minas	Pichincha	6.8	San José de Minas	2020
Rio Verde Chico	Tungurahua	10.0	Hidrosierra	2019
Hidrotambo	Bolívar	8.0	Hidrotambo	2016
Alazán	Cañar	6.2	CELEC-Hidroazogues	2016
Loreto	Chinchipe	2.3	Ecoluz	2002
Río Blanco	Chimborazo	3.0	E.E. Riobamba	1997
Illuchi No.2	Cotopaxi	5.2	E.E. Cotopaxi	1987
San Miguel de Car	Carchi	3.0	E.E. Norte	1987
Pasochoa	Pichincha	4.5	E.E. Quito	1976

Name	Location	Capacity (MW)	Operator	Launch year
Ambi	Imbabura	8.0	E.E. Norte	1968
Papallacta	Napo	6.6	Ecoluz	1965
Península	Tungurahua	3.0	E.E. Ambato	1962
La Calera	Pichincha	2.5	I.M. Mejía	1957
Carlos Mora	Zamora	2.4	E.E. Sur	1957
Los Chillos	Chimborazo	1.8	E.E. Quito	1953
Illuchi No.1	Cotopaxi	4.2	E.E. Cotopaxi	1951
El Carmen	Pichincha	8.4	EPMAPS	–
Vindobona	Pichincha	6.1	Vicunha	
Perlabí	Pichincha	2.7	Perlabí	–
Planta Chimborazo	Napo	2.0	UCEM	–

Source: ACRONEL[13]

The generation expansion plan stated in the PME was updated to consider projects to be deployed between 2021 and 2024 and to be connected to the SNI. Of these projects, SHP accounts for six, with a total capacity of 42.36 MW and expected to start operations between 2021 and 2024 (Table 2).[31]

Table 2. **List of Selected Planned Small Hydropower Projects in Ecuador**

Name	Location	Capacity (MW)	Developer	Planned launch year	Stage of development
Chalpi Grande	Napo	7.6	EPMAPS EP	2021	In construction
Mazar-Dudas, Central San Antonio	Cañar	7.2	CELEC EP - Hidroazogues	2022	Frozen
Maravilla	Pichincha	9.0	Hidroequinoccio EP	2023	Operation approval
Mazar-Dudas, Central Dudas	Cañar	7.4	CELEC EP - Hidroazogues	2024	Frozen
Soldados Yanuncay, Central Soldados	Azuay	7.2	Elecaustro S.A.	2024	Operation approval

Source: MERNNR[31]

Ecuador has a gross theoretical hydropower potential of 91,000 MW, while technical and economically feasible potentials are estimated to be 31,000 MW and 22,000 MW, respectively.31 Hence, a considerable potential capacity remains undeveloped in the country. To use some of this hydropower potential, the PME 2018–2027 considers a total of 97 hydropower projects, for a total expected capacity of 9,429 MW. Nonetheless, SHP only accounts for 3 per cent of this total expected capacity (243.65 MW), with 47 potential projects (Table 3).[31]

Table 3. **List of Selected Small Hydropower Projects Available for Investment in Ecuador**

Name	Location	Potential capacity (MW)	Type of site (new/refurbishment)
Bravo Grande	Esmeraldas	10	New
Alambi	Pichincha	9.5	New
San Pedro II	Pichincha	9.5	New
San Francisco II	Azuay	9.4	New
Tandapi	Pichincha	8.9	New

Source: MERNNR[31]

Note: Data as 5of 2018.

The former ARCONEL identified that the greatest hydropower potential in Ecuador (9.93 GW) is found in the Amazon basin. However, the latest tenders seek to strengthen the development of generation in the Pacific basin (with a potential of 3.5 GW), through economically competitive projects, to reduce issues with generation imbalance, especially during the rainy season in the Amazon basin. The Pacific basin has its maximum production from January to March, when the hydropower plants from the Amazon basin have low generation.[32]

RENEWABLE ENERGY POLICY

Ecuador has shown commitment to tackling climate change and protecting nature. The country signed the United Nations Framework Convention on Climate Change in 1992 (with no mandatory commitments), the Kyoto Protocol in 1999 and the Paris Agreement in 2016. It has implemented some climate change policies, such as the National Plan for Good Living 2013–2017, which defined climate change as a national issue and stated the need for a change in the energy mix; the National Climate Change Strategy 2012–2025, setting objectives for mitigation measures and increasing capacity building (mainly hydropower); and the National Climate Change Plan 2015–2018, among others.[33] The National Climate Change Strategy 2012–2025 focuses on adaptation and mitigation measures to reduce greenhouse gas emissions and defines priority sectors that are most vulnerable to climate change, which include energy, industry, agriculture and waste.[34]

Ecuador has committed to limit emissions, deforestation and air pollution, to guarantee the rights of nature and promote environmental sustainability, including the management of water heritage, and to restructure the energy mix to achieve energy sovereignty and sustainability by increasing renewable energy capacity. By 2017, Ecuador expected to achieve 90 per cent of clean energy coming from hydropower plants and aims to reduce its emissions in the energy sector by 20–25 per cent below the business-as-usual scenario.[34] Between 2010 and 2020, CO_2 emissions in the energy sector reduced by 3 per cent, mainly due to the commission of large hydropower plants, replacing thermal power generation. In September 2021, Ecuador reiterated its commitment to an average annual reduction of 6.5 million tons of CO_2 emissions equivalent until 2025, as stated in its Intended Nationally Determined Contributions.[35]

The electricity sector in Ecuador has shifted in recent years, with the National Plan for Good Living 2013–2017, towards more renewable generation, mainly hydropower.[31] The recent renewable energy policy is aiming towards pushing the development of new technologies to improve the electricity sector, such as hydrogen generation and battery storage.[36]

The PME aims to improve and expand generation, transmission and distribution in the electricity sector, with a total investment (public and private) of USD 12,679 million, of which USD 6,150 million (49 per cent of the total) correspond to the expansion of electricity generation capacity, including USD 4,675 million for hydropower plants. In 2020, there were 39 active projects, of which 21 were for renewable energy.[31] The last adjustments to the PME were made in August 2021 by the MERNNR, aiming to expand generation capacity by 1,440 MW by 2028, to be able to cover future demand, by pushing investments (approximately USD 2,200 million) in renewable energy (490 MW of solar power, 670 MW of wind power, 150 MW of hydropower and 130 MW of biomass). It is expected that 500 MW of this additional capacity will be operational by 2024.[37] Nonetheless, most of the expected added hydropower capacity corresponds to plants with over 10 MW in capacity.[31]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

There is no particular legislation in Ecuador regarding SHP, hence, the general Ecuadorian electricity sector legislation applies to SHP. According to article 3 of the LOSPEE, hydropower plants of small capacities are considered as non-conventional renewable energy sources in Ecuador. The General Regulation for the LOSPEE defines distributed generation as small power plants that are installed close to consumption and are connected to the grid. In May 2021, ARC issued a legal framework for distributed generation, for power plants with capacity between 100 kW and 10 MW, including hydropower.[38]

COST OF SMALL HYDROPOWER DEVELOPMENT

The total average cost of hydropower generation in Ecuador is expected to grow from USD 42 million in 2018 to USD 62 million by 2027.[25] The average cost estimations include administration, operation and maintenance costs; costs associated with quality, reliability and availability; costs associated with environmental responsibility; expansion of the electricity service (distribution activity); and the variable costs required for energy production. For private generation, it also includes the remuneration of the capital base of the assets in service, through the determination of an annuity with discount rates and defined useful lives of the plants.

Some preliminary average economic estimates for SHP projects between 2015 and 2019 estimate that the average investment cost varies between 3,017 EUR/kW (3,452 USD/kW) for low-head and 2,907 EUR/kW (3,326 USD/kW) for medium- and high-head (starting from 20 metres) projects. Average operation and management costs represent 3 per cent of total investment, the average lifetime of mechanical equipment is 25 years, the cost of civil works represents an average between 40 per cent (low-head) and 50 per cent (medium- and high-head) of total investment cost and the average internal rate of return is 20 per cent.[39]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

The electricity sector is considered strategic in Ecuador and it is the responsibility of the Government to plan, build and maintain electricity infrastructure, although it is also able to grant concessions to private actors to meet the country's needs. The MERNNR can grant concessions (through public tenders) for the deployment of new power capacity regarding non-conventional renewable energy, which includes SHP, following the PME. Nonetheless, hydropower plants shall be returned to the state by the end of each concession.[40] Incentives can be granted to the awarded parties. All requirements and incentives are published in each call for tenders, by block, following the PME. SHP plants can take between 20 and 40 years, depending on the plant capacity.[41]

Hydropower generation projects can be financed with public, private or mixed funds (through public-private partnerships). International organizations and agencies, such as the Interamerican Development Bank, United Nations and the French Development Agency, have also financed hydropower projects in Ecuador. Since 2000, the country has implemented FITs to support the deployment of renewable electricity capacity, which have evolved throughout the years regarding incentives and technologies. In 2014, the scheme implemented differentiated rates and became applicable to hydropower plants with capacity up to 30 MW.[39] Of the current 43 active SHP plants in Ecuador, 25 received public funding (representing 61.2 MW of the total SHP deployed capacity), 15 had private funding (48.6 MW) and 3 had mixed funding (2.8 MW).[42]

Ecuador has established a clear path towards the expansion of renewable capacity. In July 2021, the intended block of renewable projects increased from 200 MW to 500 MW, of which 150 MW are expected to be hydropower of less than 50 MW, with 30 years concessions (the First Block) and 36 months for construction.[43] In September 2021, the MERNNR announced a call for tenders to attract private investment of USD 875 million to build and operate these 500 MW of renewable energy projects, including solar power, wind power, hydropower of less than 50 MW (stated as SHP in the press release) and biomass.[44] The eight SHP projects (under 10 MW) included in this tender will account for a total of 55.35 MW (Table 4), with all of them already with definitive designs. The awarding mechanism will follow the lowest offered price. Participants to the tenders shall present warranties for USD 20,000 per MW of offered capacity and demonstrate financial and technical capacity.[31] Some incentives for private investors in new electricity generation projects include the exoneration of taxes on the outflow of foreign currency (ISD), 12-year exoneration of income tax in the national territory (8 years if the investment is in Quito or Guayaquil and 15 years if in a vulnerable region).[32]

Table 4. **List of Small Hydropower Projects Open for Tender in Ecuador as of September 2021**

Name	*Location*	*Potential capacity (MW)*
Chinambí	Carchi	9.95
Rayo 1	Cotopaxi	9.8
Chanchán	Chimborazo	9.1
San Mateo	Napo	7.3
Sardinas	Napo	6.6
Huapamala	Loja	5.2
Caluma Pasagua	Bolívar	4
Tigreurco	Bolívar	3.4

Source: Ministry of Energy and Non-Renewable Natural Resources[32]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

In Latin America, climate change has a potential to affect hydropower generation due to rising temperatures, fluctuating rainfall patterns, increased volumes of water due to melting glaciers and more constant extreme weather events. By the end of the century, these factors might cause a slight increase in the hydropower capacity factor in Ecuador, with increase in precipitation and average runoff volume.[45] In Ecuador, the coastal regions are projected to have more rainfall and the widespread flooding caused by the El Niño phenomenon is expected to increase. In the Andean region, hydropower capacity factors are projected to stay between +3 per cent and -3 per cent from the baseline.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Despite the great unexploited hydropower potential in Ecuador and the Government's policies and efforts to deploy new renewable generation capacity, there are still some challenges regarding the use of SHP. The following points summarize the main barriers that have been identified:

- Most of the planned projects to deploy hydropower capacity are focused on large-scale hydropower plants;
- Despite the identification of most hydropower potential in the Amazon basin, the development of most projects is focused in the Pacific basin to counteract generation imbalance, mainly in the rainy seasons;
- The country lacks detailed information regarding economic and technical potential of SHP, which might affect policy decisions and investment.

The following points summarize the main enablers for further SHP development:

- The recent regulation on distributed generation might boost the interest to invest in SHP projects;
- Ecuador might take advantage of the expected slight increase in hydropower capacity factor due to climate change and focus on the deployment of further SHP capacity;
- Recent tenders are showing bigger interest from the Government to seek investment in hydropower projects of up to 50 MW capacity, which might portray a bigger interest in SHP deployment in the coming years;
- The incentives considered in recent tenders for the deployment of new renewable capacity might also attract more interest to SHP projects.

REFERENCES

1. National Institute of Statistics and Census Instituto Nacional de Estadísticas y Censos (INEC) (2021). *Proyecciones Poblacionales. Proyección de la población ecuatoriana, por años calendario, según cantones 2010-2020*. Available at https://www.ecuadorencifras.gob.ec/proyecciones-poblacionales/ (Accessed 9 August 2021).
2. World Bank (2018). *Surface area (sq. km)*. Available at https://data.worldbank.org/indicator/AG.SRF.TOTL.K2?locations=EC (Accessed 9 August 2021).
3. Varela, L. A. & Ron, S. R. (2020). *Geografía y clima del Ecuador*. BIOWEB. Pontificia Universidad Católica del Ecuador. Available at https://bioweb.bio/fungiweb/GeografiaClima/#inicio (Accessed 30 August 2021).
4. Briney, A. (2020). *Geography of Ecuador*. Available at https://www.thoughtco.com/geography-of-ecuador-1434572 (Accessed 30 August 2021).
5. Military Geographical Institute (2013). *Infografía Clima y Factores del Clima, Geoeduca. Atlas Geográfico Nacional*. Pontificia Universidad Católica del Ecuador. Available at http://www.geoportaligm.gob.ec/geoeduca/web/bachillerato/infografias/ecuador/clima/mobile/index.html (Accessed 30 August 2021).
6. Valderrama D., Vásquez V. & León E. (2021). Cambios en patrones de precipitación y temperatura en el Ecuador, región costa. *Revista Dilemas Contemporáneos: Educación, política y valores. VIII*, Special Edition, no. 25. Available at https://doi.org/10.46377/dilemas.v8i.2608 (Accessed 30 August 2021).
7. Ministry of Environment (2019). *Primera contribución de-*

terminada a nivel nacional para el Acuerdo de París bajo la Convención Marco de Naciones Unidas sobre el Cambio Climático. Quito: Ministerio del Ambiente. Available at https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Ecuador%20First/Primera%20NDC%20Ecuador.pdf (Accessed 30 August 2021).
8. Ministry of Environment, Water Secretariat (2016). *Plan Nacional de la Gestión Integrada e Integral de los Recursos Hídricos de las cuencas y microcuencas hidrográficas del Ecuador*. Available at http://suia.ambiente.gob.ec/?page_id=495 (Accessed 1 September 2021).
9. Military Geographical Institute (2018). *Atlas de espacios geográficos expuestos a amenazas naturales y antrópicas*. Quito-Ecuador. Available at http://www.geoportaligm.gob.ec/geoeduca/web/educacion_basica/atlas/atlas_riesgos/mobile/index.html (Accessed 1 September 2021).
10. Agency for Regulation and Control of Electricity (ARCONEL) (2021). *Balance Nacional de Energía Eléctrica Agosto 2021*. Available at https://www.controlrecursosyenergia.gob.ec/balance-nacional-de-energia-electrica/ (Accessed 3 December 2021).
11. Ministry of Energy and Natural and Renewable Resources (2020). *Rendición de Cuentas 2020*. Available at https://www.recursosyenergia.gob.ec/proceso-de-rendicion-de-cuentas-2020/ (Accessed 3 September 2021).
12. Agency for Regulation and Control of Electricity (ARCONEL) (2021). *Atlas del Sector Eléctrico Ecuatoriano 2020*. Available at https://www.controlrecursosyenergia.gob.ec/wp-content/plugins/download-monitor/download.php?id=1856&force=1 (Accessed 9 September 2021).
13. Agency for Regulation and Control of Electricity (ARCONEL) (2021). *Estadística anual y multianual del Sector Eléctrico Ecuatoriano 2020*. Available at https://www.regulacionelectrica.gob.ec/estadistica-del-sector-electrico/ (Accessed 13 September 2021).
14. Ministry of Energy and Natural and Renewable Resources (2020). *Balance Energético Nacional 2019*. Available at https://www.recursosyenergia.gob.ec/5900-2/ (Accessed 3 September 2021).
15. Ministry of Energy and Natural and Renewable Resources (2021). *Balance Energético Nacional 2020*. Available at https://www.recursosyenergia.gob.ec/5900-2/ (Accessed 10 September 2021).
16. National Electricity Operator (CENACE) (2020). *Ecuador rompe récord de demanda máxima de electricidad*. Available at http://www.cenace.gob.ec/ecuador-rompe-record-de-demanda-maxima-de-electricidad/ (Accessed 3 September 2021).
17. National Electricity Operator (CENACE) (2020). *Demande de energía eléctrica del Ecuador se recupera*. Available at http://www.cenace.gob.ec/demanda-de-energia-electrica-del-ecuador-se-recupera/ (Accessed 3 September 2021).
18. National Electricity Operator (CENACE) (2021). *La demanda eléctrica del Ecuador aumentó en un 8.13%*. Available at http://www.cenace.gob.ec/la-demanda-electrica-del-ecuador-aumento-en-un-813/ (Accessed 3 September 2021).
19. Agency for Regulation and Control of Electricity (ARCONEL) (2021). *Plan Anual de Operación Estadística PAO 2021. Coordinación Técnica de Regulación y Control Eléctrico*. Available at https://www.controlrecursosyenergia.gob.ec/wp-content/uploads/downloads/2020/10/PAO-2021.pdf (Accessed 15 September 2021).
20. National Electricity Operator (CENACE) (2020). *Informe Anual 2020*. Available at http://www.cenace.gob.ec/informe-anual-2020/ (Accessed 9 September 2021).
21. United States Agency International Development (USAID) (2020). *Ecuador Energy Sector Assessment*. Available at https://pdf.usaid.gov/pdf_docs/PA00WQNF.pdf (Accessed 10 September 2021).
22. Ministry of Electricity and Renewable Energy & Inter-american Development Bank (2017). *Plan Nacional de Eficiencia Energética 2016-2035*. Available at https://www.cnelep.gob.ec/plan-nacional-eficiencia-energetica/ (Accessed 3 September 2021).
23. World Bank (2019). *Access to electricity (% of population) - Ecuador*. Sustainable Energy for All Database. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?end=2019&locations=EC (Accessed 9 September 2021).
24. Agency for Regulation and Control of Electricity (ARCONEL) (2019). *Cobertura del servicio eléctrico*. Available at https://www.controlrecursosyenergia.gob.ec/cobertura-anual-de-servicio/ (Accessed 9 September 2021).
25. Ministry of Energy and Natural and Renewable Resources (2021). *Plan Maestro de Electricidad*. Available at https://www.recursosyenergia.gob.ec/plan-maestro-de-electricidad/ (Accessed 15 September 2021).
26. Agency for Regulation and Control of Electricity (ARCONEL) (2021). *Pliego tarifario del servicio público de energía eléctrica. Enero-Diciembre 2021*. Available at https://www.controlrecursosyenergia.gob.ec/wp-content/uploads/downloads/2021/06/Anexo_1_pliego_tarifario_spee_2021.pdf/ (Accessed 9 September 2021).
27. Agency for Regulation and Control of Electricity (ARCONEL) (2020). *Resolución ARCONEL-005/2020*. Available at https://www.regulacionelectrica.gob.ec/resoluciones-pliegos-tarifarios/ (Accessed 9 September 2021).
28. UNIDO, ICSHP (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
29. UNIDO, ICSHP (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
30. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
31. Ministry of Energy and Natural and Renewable Resources (2021). *Plan Maestro de Electricidad*. Available at https://www.recursosyenergia.gob.ec/plan-maestro-de-electricidad/ (Accessed 15 September 2021).
32. Ministry of Energy and Natural and Renewable Resources (2021). *Proyectos Bloque ERNC I, 500 MW, Energía Renovable No Convencional*. Available at https://proyectos.recurso-

syenergia.gob.ec/bloqueErnc.php (Accessed 21 September 2021).
33. National Government of the Republic of Ecuador (2020). *Ecuador's Intended Nationally Determined Contribution*. Available at https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/Ecuador/1/Ecuador%20INDC%2001-10-2015%20-%20english%20unofficial%20translation.pdf (Accessed 17 September 2021).
34. Ministry of Environment (2012). *Estrategia Nacional de Cambio Climático del Ecuador 2012-2025.* Available at https://www.ambiente.gob.ec/wp-content/uploads/downloads/2017/10/ESTRATEGIA-NACIONAL-DE-CAMBIO-CLIMATICO-DEL-ECUADOR.pdf (Accessed 21 September 2021).
35. Ministry of Energy and Natural and Renewable Resources (2021). *Ecuador reafirma su compromiso de cumplir con el "Acuerdo de París", en el marco de la Conferencia de las Naciones Unidas sobre el Cambio Climático*. Available at https://www.recursosyenergia.gob.ec/ecuador-reafirma-su-compromiso-de-cumplir-con-el-acuerdo-de-paris-en-el-marco-de-la-conferencia-de-las-naciones-unidas-sobre-el-cambio-climatico/ (Accessed 21 September 2021).
36. Ministry of Energy and Natural and Renewable Resources (2021). *ACUERDO Nro. MERNNR-VEER-2021-0008-AM*. Available at http://www.cenace.gob.ec/wp-content/uploads/downloads/2021/08/MERNNR-VEER-2021-0008-AM.pdf (Accessed 17 September 2021).
37. Ministry of Energy and Natural and Renewable Resources (2021). *Ecuador actualiza su Plan Maestro de Electricidad para impulsar inversiones en Energías Renovables No Convencionales por cerca de USD 2.200 Millones*. Available at https://www.recursosyenergia.gob.ec/ecuador-actualiza-su-plan-maestro-de-electricidad-para-impulsar-inversiones-en-energias-renovables-no-convencionales-por-cerca-de-usd-2-200-millones/ (Accessed 9 September 2021).
38. Agency for Regulation and Control of Electricity (ARCONEL) (2021). *Resolución No. ARCERNNR-014/2021, por el que se expide el Marco normativo para la participación en generación distribuida de empresas habilitadas para realizar la actividad de generación*. Available at https://www.energiaestrategica.com/wp-content/uploads/2021/05/Resolucion-Nro.-ARCERNNR-014-2021-signed-signed.pdf (Accessed 23 September, 2021).
39. Minaya, V.G., Haro, P.L. & Guerra, M.J. (2020). Small Hydropower in Ecuador: Potential and prospects. *Hydropower & Dams, 6*, 2020. Available at https://www.hyposo.eu/HYPOSO_Publications/Ecuador_FINAL.pdf (Accessed 24 September 2021).
40. National Government of the Republic of Ecuador (2019). *Reglamento a la Ley Orgánica del Servicio Público de Energía Eléctrica.* Available at https://www.gob.ec/sites/default/files/regulations/2020-09/REGLAMENTO%20A%20LA%20LEY%20ORGÁNICA%20DEL%20SERVICIO%20PÚBLICO%20DE%20ENERGÍA%20ELÉCTRICA.pdf (Accessed 23 September 2021).
41. National Electricity Board (CONELEC) (2011). *Regulación No. CONELEC 003/11, Determinación de la metodología para el cálculo del plazo y de los precios referenciales de los proyectos de generación y autogeneración*. Available at https://www.regulacionelectrica.gob.ec/wp-content/uploads/downloads/2015/10/CONELEC-plazos.pdf (Accessed 23 September 2021).
42. Agency for Regulation and Control of Electricity (ACRONEL) (2021). *Reportes de Información Estadística del Sector Eléctrico, Centrales*. Available at http://reportes.controlrecursosyenergia.gob.ec (Accessed 24 September 2021).
43. Ministry of Energy and Natural and Renewable Resources (2021). *Ecuador actualiza el Bloque de Energías Renovables a 500 megavatios con potencial de inversión por USD 968 millones*. Available at https://www.recursosyenergia.gob.ec/ecuador-actualiza-el-bloque-de-energias-renovables-a-500-megavatios-con-potencial-de-inversion-por-usd-300-millones/ (Accessed 21 September 2021).
44. Ministry of Energy and Natural and Renewable Resources (2021). *El Gobierno del Encuentro presenta al sector privado proyectos de generación y transmisión eléctrica por USD 1861 millones*. Available at https://www.recursosyenergia.gob.ec/el-gobierno-del-encuentro-presenta-al-sector-privado-proyectos-de-generacion-y-transmision-electrica-por-usd-1861-millones-2/ (Accessed 21 September 2021).
45. International Energy Agency (2021). *Climate Impacts on Latin American Hydropower*. Available at https://www.iea.org/reports/climate-impacts-on-latin-american-hydropower/methodology-and-references (Accessed 23 September 2021).

French Guiana

Alberto Tena, SEDE Consulting

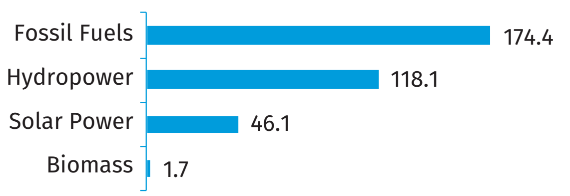
KEY FACTS

Population	281,678 (2019)[1]
Area	83,534 km2 [2]
Topography	French Guiana is situated on the north-eastern coast of South America, facing the Caribbean. The country borders Brazil to the south and east and Suriname to the west. Since 1946, it has had the status of an Overseas Department of France.3 With the exception of the coastal strip, which is made up of savannas, over 90 per cent of the country's territory is covered by rainforest. 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, including Ile de Connetable and Devil's Island located along the coast towards Brazil.[4]
Climate	French Guiana is subjected to an equatorial climate, with hot and wet weather conditions. Average temperatures vary slightly during the year, with a minimum temperature of 22 oC and a maximum temperature of up to 36 oC.[5]
Climate Change	The country is highly sensitive to climate change. Between 1955 and 2009, average temperature increased by 1.36 °C. Specifically, there is an observed increase of 1.65 °C for maximum temperatures and 1.1 °C for the average minimum temperatures.[5]
Rain Pattern	Precipitation is abundant at 3,000 mm/year, with reduced intensity in the west and the interior. There are four distinct seasons according to the pluviometry: the short rainy season lasting from the end of November to mid-February; the short summer from mid-February to the end of March; the great rainy season from April to June; and the dry season from July to mid-November.
Hydrology	There are two main rivers: the Maroni, which separates French Guiana from Suriname, and the Oyapock, located in the east and bordering Brazil for 600 kilometres. Other important rivers include the Camopi, Mana and Tompok. These are transboundary rivers and the management of their hydropower potential presupposes collaboration between the neighbouring countries.[3,6]

ELECTRICITY SECTOR OVERVIEW

Renewable energy plays an important role in electricity production in French Guiana. However, since there are difficulties with energy storage and distribution, the country still resorts to thermal power generation. The Government is focused on accelerating the energy transition and promoting sustainable energy projects, specifically, using hydropower, biomass and solar power. The total installed capacity of French Guiana in 2018 was 340.3 MW, approximately 51 per cent of which was from fossil fuels (Figure 1).[7]

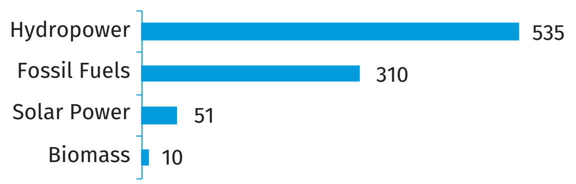
Figure 1. **Installed Electricity Capacity by Source in French Guiana in 2018 (MW)**



Source: EDF[7]

At the same time, renewable energy accounted for 66 per cent of total electricity generation in 2018, a slight reduction of 2 per cent compared to 2017.[8] This fact is linked to the conditions for hydropower electricity generation being less favourable in 2018 than the previous period. In 2018, the total production stood at 906 GWh (Figure 2), compared to 923 GWh in 2017.[7,8]

Figure 2. **Annual Electricity Generation by source in French Guiana in 2018 (GWh)**



Source: EDF[7]

French Guiana faces difficulties with supplying electricity to a large part of its territory. The littoral zone is partially interconnected by networks (except in the eastern regions), with a 414-kilometre transmission line connecting the main coastal cities of Saint-Laurent de Maroni, Kourou and Cayenne.[9] The means of electricity production for the littoral network are divided between the following power plants: the 116 MW Petit-Saut hydropower plant (EDF), which supplies on average nearly 60 per cent of the electricity consumed in French Guiana; the Dégrad des Cannes thermal power plant (EDF), which is set to be closed by 2023; the Kourou biomass power plant (Voltalia), which includes peak and back-up facilities; and other renewable energy plants, including solar photovoltaics (PV) and run-of-river hydropower.

In isolated municipalities not connected to the main grid, the means of production are limited to small electrical networks operated by EDF and supplied mainly by mini-thermal power plants and run-of-river hydropower (from the rivers Mana, Approuague, Sparouine, Maman Valentin and Inini). Almost 49 per cent of new homes built in the interior municipalities are not electrified.[10] The following municipalities are totally or partially disconnected from the electricity grid: Maripasoula, Papaïchton, Grand Santi, Saül, Saint-Georges, Camopi, Ouanary and Régina (village of Kaw).

The deficit of electric infrastructure highlights a precariousness that could be aggravated by future demographic growth.[11] Electricity demand is predicted to reach 1,280 GWh by 2030. The growing demand will have to be supplied through the construction of additional capacities, while at the same time respecting the principles established in the Multiannual Energy Programme (PPE), signed on 17 March 2017. The objective is to increase the share of renewable energy sources in electricity production to over 85 per cent by 2023.[10] However, at present, French Guiana faces important challenges in meeting this goal, since it is highly dependent on imports of fossil fuels.

Energy policies implemented by the Government are aimed at the development of modern sustainable energy infrastructure and overcoming the existing constraints, such as limited generation capacity and a lack of interconnectivity between power grids. The plans also include transmission lines to connect French Guiana to the continent's power pools and permit a large increase in interregional energy trade. The electricity transmission network of French Guiana meets the technical and economic conditions to develop such a project.

To implement energy-related policies in the territory, the local Government relies on expert entities in energy management and regulation such as the Agency for Environment and Energy Management (ADEME), Energy Regulatory Commission (CRE) and General Directorate for Territories and the Sea (DGTM). ADEME promotes and coordinates specific operations for the protection of the environment and energy management.[12] CRE is an independent authority that ensures the functioning of the electricity and gas markets in France.[13] DGTM is in charge of implementing the policies by the Ministry of the Environment, Energy and the Sea as well as those of the Ministry of Housing and Sustainable Housing.[14] The production of electricity is open to competition in French Guiana, however, according to the Law from 11 July 1975, the distribution and commercialization of electricity is monopolized by EDF.[15]

Other relevant stakeholders in the electricity sector include:

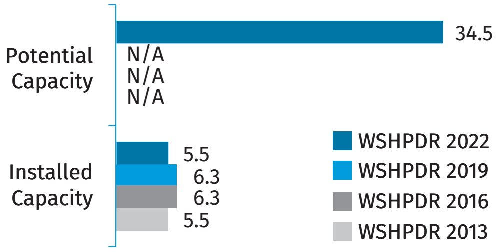
- Community of Communes of Western French Guiana (CCOG) — a public partnership entity that implements and develops rural electrification, providing specific projects for energy production (infrastructure development) as well as energy distribution (low-voltage networks);
- General Directorate of Energy and Climate (DGEC) develops and implements policies relating to energy and in particular to combating global warming and atmospheric pollution;
- French Guiana Water Office (OEG) — a public and local body in charge of water management and optimization of water as a natural resource to preserve. OEG provides studies for general interest and support for initiatives related to water treatment or energy production by hydropower systems;
- Voltalia designs and implements renewable energy projects in the country. It has carried out, among others, the hydropower project in Mana and the biomass power plant in Kourou.[16,17,18,19]

The isolation of French Guiana as an overseas territory heightens its need to produce local electricity, but at a considerable extra cost. In order to ensure that the tariffs maintain a level of equity with those of the metropole, the Government compensates the trading company EDF for these costs by means of a mechanism of tariff equalization. EDF sets different tariffs according to the power installed. For power up to 36 kV, tariffs are as follows. Tariffs for citizens range from 0.17 USD/kWh to 0.18 USD/kWh, including tax. The tariff by time slot is set at 0.20 USD/kWh, including tax, for peak hours (6 am – 10 pm) and 0.15 USD/kWh, including tax, for off-peak hours. The fixed cost for non-residential and enterprise consumers is set at 0.13 USD/kWh, excluding taxes, and the tariff by time slot is set at 0.14 USD/kWh, excluding taxes, for peak hours and 0.96 USD/kWh for off-peak hours.[20]

SMALL HYDROPOWER SECTOR OVERVIEW

The definition of small hydropower (SHP) in French Guiana is up to 10 MW. The total installed capacity of SHP is currently 5.5 MW (Table 1).[21,22] There are two SHP plants: the Saut-Maman Valentin plant in Mana and the Saut-Maripa plant in Oyapock, which has been recently refurbished. The PPE foresees the installation of run-of-river hydropower plants on the Mana River with a combined capacity of 16.5 MW between 2016 and 2023 (Table 2).[10] However, based on the planned projects, this objective will not be achieved. According to the PPE, by 2030 the total SHP installed capacity could reach 34.5 MW.[10] Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity decreased based on more accurate data and the estimate of the potential has been added (Figure 3).

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



Source: CTG,[10] Voltalia,[21] ADEME,[22] *WSHPDR 2013*,[23] *WSHPDR 2016*,[24] *WSHPDR 2019*[25]

Table 1. **List of Existing Small Hydropower Plants in French Guiana**

Name	*Location*	*Capacity (MW)*	*Plant type*	*Operator*	*Launch year*
Saut-Maman Valenti	Mana	4.5	Run-of-river	Voltalia	2012
Saut-Maripa	Oyapock	1.0	Run-of-river	EDF	1995

Source: Voltalia,[21] ADEME[22]

Table 2. **List of Planned Small Hydropower Projects in French Guiana**

Name	*Location*	*Capacity (MW)*	*Plant type*	*Developer*
Saut Belle-étoile	Mana	4.5	Run-of-river	Voltalia
Saut Sonelle	Maripasoula	3.2	Run-of-river	Voltalia

Source: ADEME,[22] DEAL[26]

Hydropower production in French Guiana is mainly concentrated at the Petit-Saut plant. Its production depends on climatic conditions and can vary considerably from one year to another. Nonetheless, the plant covers almost two thirds of the country's electricity needs. Its annual production fluctuated between 352 GWh in 2009 and 544 GWh in 2017, representing approximately 45 per cent and over 55 per cent of the electricity delivered to the main grid in those years, respectively. In 2018, the Petit-Saut plant produced approximately 510 GWh of electricity.[7]

SHP is foreseen to serve the main isolated towns on the Maroni and Oyapock Rivers. The 3.2 MW Saut Sonelle project on the Inini River, which is under appraisal, will supply Maripasoula and Papaïchton. There is also an ongoing study of a project on the Maroni River at Mankaba Soula, which is intended to supply the commune of Grand Santi.[22] The OEG carried out a study aimed at identifying SHP potential on the Maroni River, where many sites suitable for small-scale run-of-river project exist (Table 3).[27]

Table 3. **List of Potential Small Hydropower Projects in Mana Region**

Name	*Location*	*Potential capacity (MW)*	*Developer*	*Type of site (new/refurbishment)*
Grand Santi	Mankaba	1.00	Voltalia	New
Grand Santi	Abounami	1.00	Voltalia	New
Papaîcthon	Apanta pachi soula	0.50	Voltalia	New
Providence (Apatou)	Koumarou	0.15	Voltalia	New

Source: IFGR[27]

SHP production in French Guiana is marked by a drop in the dry season, requiring additional solar PV, diesel and storage. Furthermore, considering the particularities of the terrain and spatial location of hydropower generation, innovative solutions need to be provided in order to ensure the technical and economic feasibility of the projects. In this sense, the creation of adapted modular hydropower generation systems at low falls could solve the local constraints for energy generation. Ongoing projects and relevant studies are aimed at taking advantage of the small falls along the rivers, as demonstrated by the project at Trois Sauts, which is currently in a pilot phase.

RENEWABLE ENERGY POLICY

Favoured by a location close to the equator, French Guiana offers a large potential to utilize renewable energy in order to secure the needed energy supply. However, although the country has adopted an ecological transition policy, its dependence on fossil fuels remains problematic. In order to reduce the environmental footprint in French Guiana, policies must address the current constraints in terms of infrastructure and financial support.

Biomass energy is a priority in the national energy plans. However, the only operational biomass plant to date is the one in Kourou, as the plants in Saint Georges and Cacao will become functional once supply problems have been resolved. The PPE estimates an installed capacity of 40 MW from biomass by 2023 and current initiatives aim to achieve this potential. The solar PV sector has also emerged as one of the development priorities for the coming years. The targets set for 2030 by the PPE include 25 MW of solar PV with storage and 26 MW of solar PV without storage. However, the inherent difficulties in providing energy supply to inland areas are a constant and have prompted the creation of creative alternative solutions such as the development of small individual solar kits for small-scale consumption. Wind power is also in development, offering a suitable potential for exploitation in the littoral region.[28]

There is also a high interest to develop hydropower projects by the local Government, especially projects in the west of the territory, for example, in Mana. SHP projects adapted to the local needs exist, including the developed prototypes of river tidal turbines using river current. The potential of these installations could be important, especially to supply electricity to isolated inland regions. The available studies show a great potential for SHP development provided the development of innovative approaches to overcome the local constraints. Furthermore, the public bodies encourage local electricity production if connection to the transmission network is not possible, under satisfactory technical, economic and environmental conditions.

In its report published in February 2017, the CRE noted that production costs by energy technology are as follows:

- Petit-Saut hydropower plants — 120 USD/MWh;
- Saut Mama Valentin run-of-river plant —125 USD/MWh;
- Biomass power plant — 250 USD/MWh;
- Solar PV installations — 490 USD/MWh on average;
- Thermal power plants — 460–650 USD/MWh.[29]

The key laws regulating the energy sector in the country include:

- Law No. 2000-1207 of 13 December 2000 for the orientation for overseas territories (LOOM);
- Law No. 2005-781 of 13 July 2005 on the programme fixing the orientations of the energy policy (POPE);
- Law No. 2009-594 of 27 May 2009 for the economic development of overseas territories (LODEOM);
- Law No. 2015-992 of 17 August 2015 on energy transition for green growth (LTECV).[10]

COST OF SMALL HYDROPOWER DEVELOPMENT

The cost of electricity generation from hydropower in isolated regions, only accessible by pirogue, is estimated to be up to 1,530.8 USD/MWh, which is 5 times higher than the average production cost in French Guiana and 10 times higher than the selling price.

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

The Government of France has developed financial mechanisms aimed at encouraging the creation of innovative alternative solutions for renewable energy exploitation, subject to the economic viability of the projects. The public investment for the development of the hydropower sector is channelled through the French Guiana Prefecture, the French Development Agency (AFD) and the Collectivité Territoriale de Guyane (CTG), which is responsible for managing European Union funds. These entities support the developers in the preparation of their projects to ensure technical and economic feasibility and also offer financial support through such mechanisms as the allocation for infrastructure investments, provision of grants or guaranteed credits.

Additionally, other financial mechanisms for SHP include the recently launched Recovery Plan for French Guiana, a financial injection that includes the reinforcement of support for the development of renewable energy technologies.[30] The legislation of France also foresees the creation of an exceptional fund for investment in overseas territories to support the funding of projects of collective public facilities.[10]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

French Guiana is very sensitive to the climate crisis since the distribution and proportion of dry and wet seasons modify drastically the available water resources. These fluctuations are unpredictable and introduce a significant risk of supply disruption in the driest years. In order to overcome these difficulties, French Guiana opted for building thermal power plants to secure the supply, in contradiction to the plan to use 100 per cent renewable electricity production.

Hydropower plants require intelligent solutions to manage the water supply. For instance, the Petit Saut hydropower plant has an optimization system to set the water use value, which chooses the most appropriate time for using the water stored in the reservoir. In this way, its management is optimized to limit the needs for additional power requirements and to reduce the use of thermal power. This optimization system takes into account the great interannual variability of hydraulic inputs, knowing that between dry and wet years the production of the Petit Saut plant can vary by a factor of two (from 280 GWh in a dry year to 540 GWh in a wet year).[7]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The barriers to SHP development in French Guiana are as follows:

- French Guiana is highly sensitive to climate change, due to the variability of rainfall between the rainy and dry seasons;
- The development of other renewable energy sources, such as solar PV or biomass, is a priority, although numerous plans and studies to develop the SHP sector exist, especially in the east of the country;
- The remoteness of the transmission or distribution network and the environmental impacts of the projects are critical obstacles, especially in isolated areas where difficulties associated with transporting materials should be considered;
- The cost of energy production in French Guiana is considerably higher than in metropolitan France;
- There are administrative delays to obtain permissions to build electrical installations.

The enablers for further SHP development are:

- The planned closure of the Dégrad-des-Cannes thermal power plant favours the use of renewable energy sources, including SHP, to meet the country's energy demand;
- Great potential for SHP development given the variety

of suitable sites across the territory;
- Local policies favourable to the exploitation of SHP for the energy transition.

REFERENCES

1. National Institute of Statistics and Economic Studies (INSEE) (2019). *Recensement de la population en Guyane*. Available at https://www.insee.fr/fr/statistiques/6012651 [in French] (Accessed 10 April 2022).
2. National Institute of Geographic and Forest Information (IGN) (n.d.). Official website. Available at https://www.ign.fr/institut [in French] (Accessed 10 April 2022).
3. Collectivité Territoriale de Guyane (CTG) (2021). *Élements de Géographie*. Available at https://www.ctguyane.fr/geographie/ [in French] (Accessed 10 April 2022).
4. New World Encyclopedia (n.d.). *French Guiana*. Available at https://www.newworldencyclopedia.org/entry/Guyana (Accessed 10 April 2022).
5. Moisan M., Habchi-Hanriot N., Collard F.X. & Fontaine M. (eds.) (2013). *Le changement climatique en Guyane: conséquences potentielles et pistes de réflexion pour l´adaptation régionale*. Rapport final. Available at https://side.developpement-durable.gouv.fr/GUAD/doc/SYRACUSE/339841/le-changement-climatique-en-guyane-consequences-potentielles-et-pistes-de-reflexion-pour-l-adaptatio [in French] (Accessed 10 April 2022).
6. Regional Directorate of Environment, Land Settlement and Housing (DREAL) (n.d.). *Schéma Directeur d´Aménagement et de Gestion des Eaux. SDAGE 2016-2021*. Available at http://www.occitanie.developpement-durable.gouv.fr/sdage-schema-directeur-d-amenagement-et-de-gestion-r8756.html [in French] (Accessed 10 April 2022).
7. EDF (2020). *Bilan prévisionnel offre/demande d´électricité 2019-2020*. Available at https://www.edf.gf/sites/default/files/SEI/producteurs/guyane/bilan_previsionnel_guyane.pdf [in French] (Accessed 10 April 2022].
8. EDF (2018). *Systèmes Energétiques Insulaires Guyane. Bilan prévisionnel de l´équilibre offre-demande d´électricité 2018*. Available at https://www.edf.gf/sites/default/files/SEI/producteurs/guyane/edf_sei_bp2018_guyane.pdf [in French] (Accessed 11 April 2022).
9. EDF (2020). *Schéma de Raccordement au Réseau des Energies Renouvelables de la Guyane*. Available at http://www.guyane.developpement-durable.gouv.fr/IMG/pdf/200227_s2renr_guyane_-_version_definitive.pdf [in French] (Accessed 11 April 2022).
10. Collectivité Territoriale de Guyane (CTG) (2016). *Programmation Pluriannuelle de l'énergie (PPE) 2016-2018 et 2019-2023 de la Guyane*. Available at https://www.guyane.gouv.fr/content/download/9870/68617/file/20161129_impacts%20eco%20et%20socio_projet%20PPE%20Guyane.pdf [in French] (Accessed 11 April 2022).
11. National Institute of Statistics and Economic Studies (INSEE) (2019). *La population guyanaise à l'horizon 2050 : vers un doublement de la population?* Available at https://www.insee.fr/fr/statistiques/3902223 [in French] (Accessed 11 April 2022).
12. Agency for Environment and Energy Management (ADEME) (2021). *L'ADEME en Guyane*. Available at https://www.guyane.ademe.fr/ [in French] (Accessed 11 April 2022).
13. Energy Regulatory Commission (CRE) (2019). *Penser l'energie de demain*. Available at https://www.cre.fr/content/download/22411/file/RA-2019.pdf [in French] (Accessed 11 April 2022).
14. General Directorate for Territories and the Sea (DGTM) (2021). *La DGTM Guyane*. Available at http://www.guyane.developpement-durable.gouv.fr/la-dgtm-guyane-r309.html [in French] (Accessed 11 April 2022).
15. EDF (n.d.). Official website. Available at https://www.edf.gf [in French] (Accessed 11 April 2022).
16. Ouest Guyane (2018). *Electrification rurale*. Available at https://ouestguyane.fr/les-activites/electrification-rurale/ [in French] (Accessed 11 April 2022).
17. Ministry of Ecological Transition (2021). *Direction Generale de l'Energie et du Climat (DGEC)*. Available at https://www.ecologie.gouv.fr/direction-generale-lenergie-et-du-climat-dgec [in French] (Accessed 11 April 2022).
18. French Guiana Water Office (OEG) (n.d.). Official website. Available at https://eauguyane.fr/ (Accessed 11 April 2022).
19. Voltalia (n.d.). Official website. Available at www.voltalia.com (Accessed 11 April 2022).
20. EDF (2021). *Grille de Prix – Tarif Bleu Feb 2021*. Available at https://particulier.edf.fr/content/dam/2-Actifs/Documents/Offres/Grille_prix_Tarif_Bleu.pdf [in French] (Accessed 11 April 2022).
21. Voltalia (2019). *Portfolio global of Creations – Hydroelectricity*. Available at https://issuu.com/voltalia/docs/renewable-portfolio_en-fr-pt_2019_links_v2 [in French] (Accessed 11 April 2022).
22. Agency for Environment and Energy Management (ADEME) (2021). *Hydraulique Guyane*. Available at https://www.guyane.ademe.fr/expertises/energies-renouvelables/hydraulique [in French] (Accessed 11 April 2022).
23. UNIDO, ICSHP (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
24. UNIDO, ICSHP (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
25. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
26. Directorate of Environment, Land Settlement and Housing (DEAL) Guiana (2018). *Rapport Avril 2018 - Projet Hydroélectrique de Saut Belle Etoile*. Available at http://www.guyane.developpement-durable.gouv.fr/IMG/docx/partie_1_rapport_du_c.e._belle_etoile_-_6_avril_2018_final_deal.docx [in French] (Accessed 11 April 2022).
27. Initiative for the future of great rivers (2019). *Synopsis sheets Rivers of the World - The Maroni*. Available

at https://www.initiativesrivers.org/wp-content/uploads/2019/03/Synopsis-sheets-MARONI-UK_2019-pdf.pdf (Accessed 11 April 2022).
28. Dubois, A. (2012) *Schéma Régional Éolien de Guyane*. Available at http://www.guyane.developpement-durable.gouv.fr/IMG/pdf/Schema_Regional_Eolien_guyane_VF_26062012.pdf [in French] (Accessed 11 April 2022).
29. Energy Regulatory Commission (CRE) (2017). *Rapport Février 2017. Mission de la CRE en Guyane*. Available at https://www.cre.fr/Documents/Publications/Rapports-thematiques/Rapport-sur-la-mission-de-la-CRE-en-Guyane [in French] (Accessed 11 April 2022].
30. Prefecture of Guiana (2020). *France Relance en Guyane*. Available at https://www.guyane.gouv.fr/content/download/18187/127740/file/fiche_france_relance_en_guyane.pdf [in French] (Accessed 11 April 2022].

Guyana

Tobias Dertmann, Hydropower Consultant; and International Centre for Small Hydro Power (ICSHP)

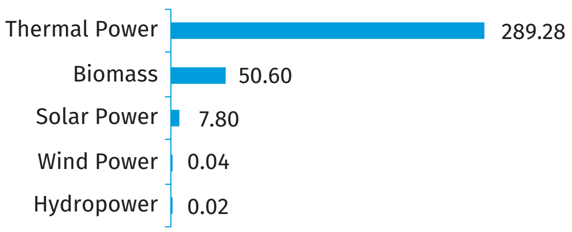
KEY FACTS

Population	743,699 (2019)[1]
Area	214,999 km2 [2]
Topography	The terrain of Guyana is mainly characterized by 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 the country.[2,3]
Climate	The climate is tropical, characterized by high temperatures and humidity. Temperatures average 25 °C with little variation throughout the year.[3]
Climate Change	The main impacts of climate change in Guyana include: increases of heavy rainfall, possibly leading to flooding; longer periods of draught; sea level rise and storm surges, especially in coastal zones; and increases in temperature and decrease of annual precipitation. It is expected that temperatures will increase by 1-4 °C in the country by the end of the century, while sea levels will rise by 0.3-0.9 metres.[4]
Rain Pattern	Precipitation is generally high, ranging from 1,500 mm to over 4,000 mm, with a pronounced rainy season from May to July and a shorter one from December to January.[3]
Hydrology	Guyana is called the Land of Many Waters owing to the abundance of streams, rivers and creeks. The largest waterways are the Corentyne, Berbice, Essequibo and Demerara 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.[3]

ELECTRICITY SECTOR OVERVIEW

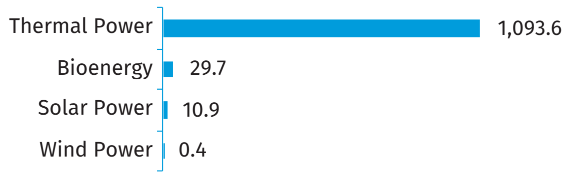
The electricity system of Guyana consists of an integrated network at the coast, which supplies electricity to approximately 90 per cent of the population, various clustered island systems in Region 3 (Essequibo Islands–West Demerara), six Hinterland island grids and self-generators, which supply individual smaller communities and mines. Installed capacity in Guyana reached a total of 347.7 MW in 2018 and renewable sources made up almost 17 per cent of the total (Figure 1).[5] Total electricity generation in 2019 stood at 1,134 GWh, with thermal power having surpassed any other source, at 1,094 GWh (Figure 2).

Figure 1. **Installed Electricity Capacity by Source in Guyana in 2018 (MW)**



Source: ETI[5]

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

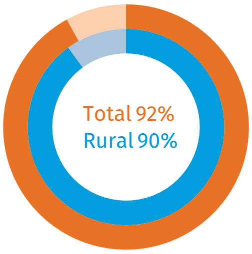


Source: GEA,[6] Guyana Chronicle[7]

While the electrification rate at the coast is high, most of the Hinterland communities do not have a regular electricity supply. In 2019 the nationwide electrification rate stood at 92 per cent, including 97 per cent in urban areas and 92 per cent in rural areas (Figure 3).[8]

The country's primary electricity utility is Guyana Power and Light Inc. (GPL), a wholly state-owned, vertically integrated utility company whose licence will expire in 2024. In many smaller Hinterland communities such as Lethem, Mahdia and others, state-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 operations that supply the nearby communities with electricity.

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



Source: World Bank[8]

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 and limited contributions from hydropower and wind. In 2020, GPL demand from its customers in the coastal area was forecasted at 926 GWh.[9]

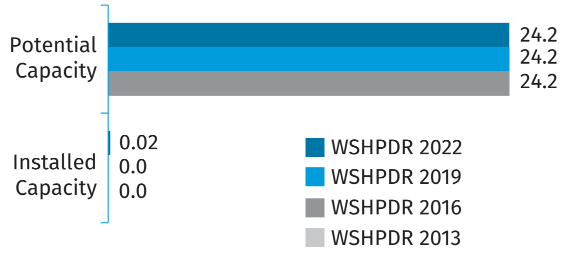
The Public Utilities Commission (PUC) regulates the electricity sector. The National Energy Policy and the Electricity Sector Reform Act (with 2010 amendments) provide the platform for the participation of independent power producers (IPPs). The Guyana Energy Agency (GEA) is mandated to advise the Minister with the responsibility for electricity and energy on matters related to energy, execute studies, formulate energy policies and regulate the import of petroleum products. However, GEA has no general role as an electricity or energy sector regulator. Besides GEA, there is the Hinterland Electrification Company Inc. (HECI), which is attached to the Office of the Prime Minister and is responsible for the electrification of the Hinterland communities. The office of the Minister with responsibility for energy, currently the Prime Minister, issues licences for IPPs or electric utilities.

GPL's electricity tariff rates for residential, commercial and industrial consumers are USD 0.22, USD 0.32 and USD 0.29 per kWh on average, respectively. Rates in the Hinterland systems are higher with the generation cost reaching as high as USD 0.50/kWh. Current electricity tariffs are by far not cost-reflective and the Government subsidizes Hinterland and GPL's operations when fuel prices are high.[9] The Government of Guyana is currently working on the 165 MW Amaila Falls hydropower project, which will significantly aid in the reduction of the overall cost of generation, and by extension, reduce electricity tariffs. The project will also improve the technical stability of the power grid with an energy mix that will include intermittent renewable energy sources.[9]

SMALL HYDROPOWER SECTOR OVERVIEW

The definition of small hydropower (SHP) used by Guyana applies to capacities up to 5 MW. The potential capacity for SHP is estimated to be 24.2 MW for the 5 MW threshold and 92 MW for the 10 MW threshold. Installed capacity was 0.02 MW as of 2021. Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, the potential capacity remained unchanged, and the installed capacity has increased due to a newly commissioned plant (Figure 4).

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



Source: Guyana Chronicle,[7] *WSHPDR 2016*,[10] *WSHPDR 2019*[11]

Note: Data for SHP up to 5 MW.

In 2019, a new SHP plant (Hosororo) was assessed and built (Table 1). This comes several years after the shutdown of the 500 kW Moco-Moco hydropower plant in 2003, following damages caused by a landslide. The Hosororo project was technically and financially supported by the German Development Agency (GIZ) and developed by GEA. It has an installed capacity of 20 kW and is connected to the small local distribution network, feeding into the electrical grid of the Mabaruma Power Company. The gross head is approximately 32 metres. The inlet structure is connected to the turbine house via a 300-metre-long pipeline. As the first hydropower plant to be restarted after more than 20 years, the project also serves as a signal to the whole hydropower sector in the country to increase the ambition within the responsible institutions.[6]

The planning, construction and commissioning for the Hosororo plant was carried out by the GEA. The project is considered as a capacity building project to increase the training of local hydropower engineers and a potential training and testing hub for the entire Caribbean (CARICOM) region. With the construction of the plant, other hydropower projects in the country have been accelerated in development (Table 2). Nevertheless, continuous operation and grid feeding into the local supply network has already taken place in the test phase and is to be operated on an ongoing basis.

Table 1. **List of Operational Small Hydropower Plants in Guyana**

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Plant type*	*Operator*	*Launch year*
Hosororo	Mabaruma	0.17	32	Run-of-river	Mabaruma Power Company	2019

Source: Guyana Chronicle[7]

The Islamic development bank (IsDB) is financing the rehabilitation of the Moco-Moco hydropower plant (700 kW) and a new construction of the Kumu (1.5 MW) plant. The tender for the double project was planned to be launched in 2021. The project will be integrated into the Lethem Power Company's electrical system. The fast-growing border town in the south-west of the country aims to generate 100 per cent of its electricity from renewable sources in the near future. The two hydropower projects will play a key role in achieving this goal.[12]

The 0.5 MW (2 x 0.25 MW) Moco-Moco hydropower project, located in Region 9, was first commissioned on 22 November 1999. The hydropower plant was designed and built by the Institute of Water Conservancy and Hydropower (Shijiazhuang, China) through a joint arrangement between the Governments of Guyana and China. The Moco-Moco plant is a run-of-river, diversion-type with a high-water head. It supplied power to the community of Lethem and its environs. However, severe rainstorms and the subsequent landslide in 2003 resulted in a fractured penstock. The Government has since been actively discussing options for its restoration. A geotechnical survey to inform the project design and assist in de-risking the project was expected to be completed in 2021.

The current concept of the project is to rehabilitate the defunct hydropower plant and increase the installed capacity to 0.7 MW. The site is located on the Moco-Moco Creek, which is a part of the Amazon River system originating from the north of the Kanuku Ranges and converging into the Takutu River. The project will provide electricity to Lethem and its environs and will form a complementary suite of planned energy initiatives in the town, consisting of the hydropower plant and a solar photovoltaic (PV) installation.

The proposed Kumu hydropower project entails the installation of a 1.5 MW plant and construction of a transmission line.[13] The Kumu Creek, located in Region 9 (Upper Takutu–Upper Essequibo), is also part of the Amazon River system. The Kumu site is situated 9.5 kilometres away from the Moco-Moco plant and 13 kilometres south-east of the town of Lethem. The project will operate as a run-of- river plant with an ultra-high head potential of more than 500 metres. Its topographical specifications can accommodate the construction of a small reservoir on the top of the mountain plateau to maintain a constant water level for operation of the plant. The combined operation of the Kumu and Moco-Moco hydropower plants, together with the planned solar PV installation, could result in 100 per cent renewable electricity generation in Lethem.

Studies have estimated the potential capacity at selected sites, such as Eclipse Falls (3–5 MW) and Tumatumari (1.5 MW). Tumatumari, utilizing water from the Tumatumari Falls on the Potaro River, Region 8, was constructed in 1957 by British Guiana Goldfields Limited and operated until 1959 when mining operations ceased. In 1969, the Government of Guyana recommissioned the plant to serve the Guyana National Service Camps at Tumatumari and Konawaruk. The development included an embankment dam, a concrete overflow dam and a two-unit powerhouse with an installed capacity of 1,500 kW using two 750 kW Francis turbines.[16]

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

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Plant type*	*Developer*	*Planned launch year*	*Stage of development*
Kumu	Kumu River, Region 9	1.50	550	Run-of-river	GEA	2024	Tender
Moco-Moco	Region 9	0.70	210	Run-of-river	GEA	2024	Tender
Kato New Build	Kato, Region 8	0.15	35	Run-of-river	GEA	2021	Construction
Tumatumari	El Paso, Region 8	2.20	–	Run-of-river	Unknown private company	–	Planning / rehabilitation
Ikuribisi	Region 7	1.00	–	Run-of-river	GEA	–	Planning

Source: Department of Public information,[14] I News Guyana[15]

In continuing efforts to collect data on potential hydropower sites for future development, hydrological data collection continued at Paruima, Region 7. A technical assessment was conducted at Chenapau, Region 8, to explore the possibility of developing a pico-hydropower plant.[16] Some SHP projects available for investment are listed in Table 3.

Table 3. **List of Small Hydropower Projects Available for Investment in Guyana**

Name	*Location*	*Potential capacity (MW)*	*Head (m)*	*Type of site (new/refurbishment)*
Semang	Marapaikru River	5.0	69	New
Kaburi	Kaburi River	5.0	62	New
Maparri	Maparri River	4.0	544	New
Wamakaru	Wamakaru River	2.5	215	New
Eclipse Falls	Barima River	3–5	7	New

Source: Dertmann[16]

RENEWABLE ENERGY POLICY

In order to preserve the country's rich fauna and flora, each new project must be scrutinized for 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 experience of setting rules for environmental evaluation and further elaboration thereof will be required. Currently, the Government prepares to attract developers of SHP projects by means of public tendering processes for selected projects.

The procurement process follows the following steps: approval of tender documents, advertisement and purchase of tender, submission of bidding documents, evaluation, approval of the evaluation report, contract award, execution, monitoring and evaluation, defects liability period and project closure. The Public-Private Partnership (PPP) Policy Framework was developed in 2018 for infrastructure projects including hydropower plants and other renewable energy projects. The details of the PPP process have not been put into practice yet for hydropower plants and energy farms.

The National Energy Policy of Guyana of 1994 contains an outlook from 1994 to 2004.[17] In 1994, the policy already prescribed energy conservation and a preference for domestic energy sources over imported fuels. The 1994 policy was outdated and required updating considering the latest technological and other developments. The Low Carbon Development Strategy (2013) aims to introduce climate smart infrastructure and the use of clean energy, installation of energy efficiency and conservation technologies as well as rural electrification programmes.[18] The National Energy Policy was updated in the form of a Green Paper in 2017.[19] Presently, the Government of Guyana aims to provide affordable, stable and reliable energy to benefit both households and businesses and will pursue a programme with an energy mix that includes hydropower, natural gas, solar and wind power. This programme will lead to more than 400 MW of newly installed capacity for residential and commercial users over the next five years and a reduction in the cost of energy by at least 50 per cent. There are currently no feed-in tariffs for electricity generated from renewable energy sources but this remains a priority.

The Electricity Sector Reform Act (ESRA) of 1999 mentions the use of renewable and alternative energy but does not explicitly promote the use thereof by creating preferences or other incentives.[5,15] Nonetheless, a study was conducted on the legal and regulatory framework of the electricity sector with a view to facilitate private sector investment in renewable energy development through IPPs and distributed generation. The study has proposed amendments to the ESRA and other relevant laws.

In the past, there was no structured approach to developing the country's hydropower resources. Instead of taking a proactive role in developing the resources by tendering concessions or generation capacity portfolios, the Government responded to proposals brought forward on the initiative of individual developers. The current approach to public tendering of projects outlines rules for participants in the bidding process. In 2016, the Cabinet issued instructions to invite proposals from interested groups for renewable energy projects supply in the Bartica community, Lethem (Moco-Moco) and other identified communities.[20] However, alternative funding sources were subsequently secured and the projects in these communities are now being developed through engineering, procurement and construction (EPC) contracts.

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 applies to planning licences, operating licences, environmental permits and any other applicable permits. This results in uncertainty for developers regarding the application duration, application cost and likely outcomes. 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. The Government of Guyana has also introduced an online platform for investors.

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

The National Energy Policy of 1994 speaks of SHP in the capacity range between 500 kW and 5,000 kW. Currently, hydropower initiatives are considered and supported by the Government.[21] The Guyana Power Sector Policy and Implementation Strategy was passed by the Cabinet in 2010 outlining the way forward for hydropower development.[22] Additionally, the Low Carbon Development Strategy (2013) included the Amaila Falls hydropower project as a major part of the country's renewable energy transition.

Country-specific estimates on the cost of SHP are not yet available due to the statistically insignificant number of operational projects in the country.

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

Value-added tax and import duty exemptions are applied to machinery and equipment for obtaining, generating and utilizing energy from renewable energy sources, including solar panels, solar lamps, deep-cycle batteries, solar generators, solar water heaters, solar cookers, direct current (DC) solar refrigerators, DC solar freezers, DC solar air conditioners, wind turbines, water turbines and power inverters. There is also a one-off tax holiday of two years for corporation tax applicable to importers of items for wind and solar energy investments. Moreover, investments (with the exception of wind and solar power) may also benefit from exemptions from property, corporate, withholding and capital gain taxes at the discretion of the Minister of Finance for periods of five or more years depending on the type of new employment created.[23]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Due to the general extremely high annual tropical precipitation amounts, there is no significant impact of the climate crisis on the operation and planning of hydropower plants. Different climate models offer different estimates of the changes in precipitation amounts. Locally, both increases and decreases in total precipitation amounts are expected. The projected change in precipitation amounts is on average approximately 100 mm/year.[4] This corresponds to a change of approximately 4 per cent per year. The possible impact on the hydropower systems can therefore be classified as low in Guyana.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Guyana has an outstanding and yet unexplored hydropower potential, including a great number of SHP sites throughout the country that remain completely undiscovered. The Hosororo SHP plant built in 2019 was the first milestone for the further development of hydropower in the country. Since then, more projects have been launched and many more are to follow. After decades of stagnation, many new competencies in hydropower have been achieved in recent years. However, there are more hurdles ahead to further incentivize developers and investors. 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.

The following points summarize the main barriers that have been identified:

- The great distances between hydropower sites and load centres and the difficult access into the Hinterland;
- 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 agencies and 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;
- Quantity and quality of hydrological and meteorological data to support hydropower development;
- Access and understanding of suitable software and satellite data for the generation of hydrological models to support hydropower development;
- Poorly gauged or ungauged rivers for the collection of physical data (flow, water level, rainfall, etc.)[8]

The following points summarize the main enablers that have been identified:

- Guyana has nearly four times its per capita economic output since 1990, triggering the development of internal hydropower capacities after years of stagnation in the past;
- the commitment of individual decision-makers in the country has meant that, despite major hurdles, the first (after 20 years) small hydropower station was able to start operating in 2019;
- Increased investment flows in SHP projects from the GEA in recent years.

REFERENCES

1. Bureau of Statistics, Guyana (2019). *Estimated Year-end and Mid-year Population by Gender, Guyana 1922 to 2019*. Available at https://statisticsguyana.gov.gy/data/data-tables/ (Accessed 22 June 2021).
2. Encyclopaedia Britannica (2018). *Guyana*. Available at https://www.britannica.com/place/Guyana#ref26769 (Accessed 22 June 2021).
3. United Nations Food and Agriculture Organization (FAO) (2015). *Aquastat database: Guyana*. Available at www.fao.org/nr/water/aquastat/countries_regions (Accessed 22 June 2021).
4. Office of Climate Change, Guyana (n.d.) *How will Climate Change Affect Guyana?* Available at https://climatechange.gov.gy/en/ (22 June 2021).
5. US Department of Energy, Energy Transitions Initiative (2018). *Guyana Energy Snapshot*. Available at https://www.energy.gov/sites/prod/files/2020/09/f79/ETI-Energy-Snapshot-Guyana_FY20.pdf (Accessed 22 June 2021).
6. Guyana Energy Agency (2019). *Annual Report 2019*. Available at https://gea.gov.gy/downloads/annual-reports/2019-anual-report.pdf (Accessed 22 June 2021).
7. Guyana Chronicle (2019). *Hosororo hydropower Project for June commissioning*. Available at https://guyanachronicle.com/2019/04/28/hosororo-hydropower-project-for-june-commissioning/ (Accessed 22 June 2021).
8. World Bank (2016). *Guyana. Access to electricity (% of population)*. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=GY (Accessed 22 June 2021).
9. Guyana Power and Light Incorporated (GPL) (2020). *Development and Expansion Programme 2021-2025*. Document provided to the author by GPL. Not yet published online.
10. UNIDO, ICSHP (2016). *World Small Hydropower Development*

Report 2016. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.

11. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
12. Islamic Development Bank (2020). *General procurement notice. Cooperative Republic of Guyana small hydropower project. Guyana energy sector general procurement notice. Mode of Financing: Installment Sale Financing No. GUY1015*. Available at https://www.isdb.org/project-procurement/tenders/2020/gpn/general-procurement-notice-cooperative-republic-guyana-small-hydropower-project (Accessed 30 June 2021).
13. Guyana Chronicle (2019). *Kumu hydro project moves forward*. Available at https://guyanachronicle.com/2019/07/24/kumu-hydro-project-moves-forward/ (Accessed 30 June 2021).
14. Department of Public Information (2019). *$450 Hydropower Plant for Kato Village*. Available at https://dpi.gov.gy/450m-hydropower-plant-for-kato-village/ (Accessed 30 June 2021).
15. I News Guyana (2019). *$450M contract awarded for hydropower plant at Chiung River*. Available at https://www.inewsguyana.com/450m-contract-awarded-for-hydropower-plant-at-chiung-river/ (Accessed 30 June 2021).
16. Internal information provided by the author and by the Guyana Energy Agency
17. Guyana Energy Agency (1994). *National Energy Policy*. Available at http://gea.gov.gy/pdf/Energy-Policy-of-Guyana-July-1994.pdf (Accessed 30 June 2021).
18. LEDS Global Partnership (2013). *Low Carbon Development Strategy*. Available at https://ledsgp.org/resource/guyana-low-carbon-development-strategy/?loclang=en_gb (Accessed 30 June 2021).
19. Bauer et al. (2018). *Discussion of Guyana's Green Paper on "Managing Future Petroleum Revenues and Establishment of a Fiscal Rule and Sovereign Wealth Fund"*. Available at https://resourcegovernance.org/sites/default/files/documents/discussion-of-guyana-green-paper.pdf (Accessed 30 June 2021).
20. Hinterland Electrification Company INC. (2016). *Special Notice - Request for Renewable Energy Proposals for Bartica*. Available at http://www.electricity.gov.gy/index.php/news/21-special-notice-request-for-renewable-energy-proposals-for-bartica (Accessed 30 June 2021).
21. Frankfurt School - UNEP Collaborating Centre for Climate & Sustainable Energy Finance (2012). *Case Study: The Guyana REDD-plus Investment Fund (GRIF)*. Available at http://www.fs-unep-centre.org/ (Accessed 30 June 2021).
22. The National Energy Policy Committee (1994). *Energy Policy of Guyana*. Available at http://goinvest.gov.gy (Accessed 30 June 2021).
23. Item 49 (a) of the First Schedule, Part III B (ii) of the Customs Act, Chapter 82:01, and Paragraph 12 of Schedule II of the Value-Added Tax Act, Cap 81:05. Available at https://www.gra.gov.gy/wp-content/uploads/2019/07/VATAct-Jan2019.pdf (Accessed 30 June 2021).

Paraguay

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

KEY FACTS

Population	7,132,530 (2020)[1]
Area	406,752 km2 [2]
Topography	Approximately two thirds of the country is covered by the Gran Chaco, a flat tropical region extending north-west into Bolivia and Argentina. Separated by the central Paraguay River, the Paraná Plateau in the eastern region is 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 country's highest peak, Mount San Rafael at 850 metres, is located in the Cordillera de San Rafael in the south-east.[2]
Climate	The climate is tropical in the north-western Chaco region and subtropical in the south-eastern Paraneña region. The winter season lasts from May to August, with July being the coldest month. Temperatures typically remain between 16 °C and 24 °C, but near freezing temperatures accompanied with frost will occasionally occur. The summer season lasts from October to March, with January being the warmest month. Daytime temperatures reaching 38 °C are common. Summer is also the wetter season with increased humidity and rainfalls.[2]
Climate Change	Climate change is expected to largely affect the precipitation pattern in the country. While the drier El Chaco region in the west will most likely experience an increase in droughts, the wetter Paraneña region in the east expects an increase in floods. Average temperatures are expected to increase by between 2.6 °C and 4.8 °C by the end of the century, depending on human acitivity.[3]
Rain Pattern	There are regional and seasonal variations in rainfall. The eastern region receives the most rainfall with an average of 1,650 mm per year. The western region is considerably drier, receiving an average of 760 mm per year. Throughout the country, rainfall is heaviest between October and April.[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 Paraguay River runs from north to south, splitting the country into its two major regions. The major tributaries entering the Paraguay River from the east are the Apa, Aquidabán, Ypané, Jejuí Guazú and Tebicuary Rivers. The Paraná River outlines the country's eastern and southern borders. The major tributaries are the Acaray and Piratiy Rivers. The country has two major lakes, Lake Ypoá and Lake Ypacaraí; both are situated towards the south.[2]

ELECTRICITY SECTOR OVERVIEW

Paraguay is a country with abundant energy resources, particularly hydropower, and has one of the world's highest electricity generation rates per capita (approximately 6,500 kWh).[4] In 2020, total electricity generation in the country was 46,373 GWh; 46,371.1 GWh of which was from hydropower and the remaining 1.9 GWh from thermal power (Figure 1). Of the total generated, 28,004 GWh, or 60 per cent, was exported, primarily to Brazil and Argentina. The total electricity consumed in Paraguay in 2020 was 13,719 GWh, of which 47 per cent was used by the residential sector, 49 per cent was used by the industrial and commercial sectors and 4 per cent was used for public street lighting. Losses accounted for the remaining over 4,000 GWh of electricity.[5]

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

Source: VMME[5]

The total installed capacity of Paraguay is approximately 8,816 MW (Figure 2). Most of the capacity comes from two binationally operated hydropower plants (HPPs). The Itaipú HPP, jointly operated with Brazil, provides 7,000 MW to Paraguay and a further 1,600 MW are from the Yacyretá HPP, jointly owned with Argentina. There is also the 210 MW Acaray HPP, which is solely Paraguayan owned.[4] Ongoing projects to connect all remote areas to the hydropower network have resulted in the recent closing of almost all thermal power generation, with the exception of 6.1 MW remaining in El Chaco region.[6] In 2019, the country reached a 100 per cent electrification rate, including all rural areas.[7]

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

Source: VMME[4]

While the electricity sector in Paraguay is virtually 100 per cent sourced from hydropower, the total energy production mix including energy used for transportation or industrial processes also features a significant amount of biomass. In 2020, 53 per cent of total energy produced was from hydropower and 47 per cent from biomass. Any petroleum-derived energy used in the transportation and industry sectors was all imported.[8]

The Vice Ministry of Mines and Energy (VMME), created in 1990, is the governmental body that oversees the energy sector as a whole. The National Administration of Electricity (ANDE) is a state-owned utility that controls the electricity subsector, including generation, transmission and distribution. ANDE is responsible for operating the share of Paraguay in the binational HPPs and fully runs the Acaray HPP. ANDE operates the bulk of the transmission and distribution network, but there are also some small, private distributors connected to the national grid, such as CLYFSA and COOPERATIVA MENONITA.[4,8]

The tariffs for the electricity sector are determined by ANDE, as per Law 2199/03, and vary depending on the type and volume of consumption (Table 1).[9] The Social Rate of Electricity Law 3480/2008 stipulates that people of a lower income level who fulfil certain requirements can pay the discounted, social tariff. This provides a 75 per cent discount for users of under 100 kWh per month, 50 per cent discount for users of between 101 kWh and 200 kWh and a 25 per cent discount for users of between 201 kWh and 300 kWh.[10]

Table 1. **Electricity tariffs in Paraguay**

Type	*Average tariff (USD/kWh)*
Residential	0.059
Industrial	0.043
Government	0.052
Street lights	0.055
Other	0.052
Export	0.120

Source: ANDE[9]

The electricity system of Paraguay is prone to high system losses, frequent blackouts and shortages during inclement weather, which can negatively affect commercial activities in the country. The two HPPs that supply most of the power for the whole country are both located on the eastern and southern national borders and are therefore far from the central, western and northern regions. Due to limited capacity on the insufficiently developed transmission and distribution network, efficient transfer of the energy is a challenge, resulting in the losses and shortages.[11]

At the same time, the demand for electricity is expected to grow both in Paraguay and the neighbour countries it exports hydropower to. In order to increase the efficiency of the current network and satisfy the demand increase, a 2021–2030 Works Master Plan was created. In this plan, several projects that will modernize the transmission system were outlined. Included is the construction of new transmission lines, some more than 200 kilometres in length. The total cost is expected to be more than USD 126 million.[12]

SMALL HYDROPOWER SECTOR OVERVIEW

The definition of small hydropower (SHP) in Paraguay is up to 50 MW. As of 2021, there were no SHP plants in operation. While total SHP potential is unknown, based on the projects planned to be completed by 2036, it is possible to conclude that there is at least 116.3 MW of undeveloped potential.[13] Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, both installed and potential SHP capacity remained unchanged since none of the planned projects have been completed during these years (Figure 3).

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

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

Paraguay has an outstanding 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.[14] Under the 2021–2040 Generation Master Plan released by ANDE in February of 2021, the construction of several SHP plants is foreseen in order to increase the energy stability as well as offer economic opportunities in remote areas. With the completion of these smaller, more spatially spread-out plants it is hoped that losses and shortages will significantly decrease along with the reliance on the three existing hydropower plants. There are plans to install 18 SHP plants between 2029 and 2036 with a combined capacity of 116.3 MW (Table 2).[13] All of these 18 plants will feature two turbines, with each turbine having half of the total capacity listed for the plant.

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

Name	*Capacity (MW)*	*Planned year of completion*
Ypané 1	3.2	2029
Ypané 2	4.2	2029
Ypané 3	4.2	2029
Ypané 4	4.3	2029
Ypané 5	5.0	2029
Ñacunday 1	8.0	2031
Ñacunday 2	4.3	2031
Carapá 1	19.0	2032
Carapá 2	4.3	2032
Itambey	5.0	2032
Jejui 1	7.0	2034
Jejui 2	10.0	2034
Jejui 3	5.4	2034
Tembey 1	3.6	2035
Tembey 2	11.0	2035
Tembey 3	3.6	2035
Pirajui	8.6	2035
Capiibary	5.6	2036
Total	**116.3**	

Source: ANDE[13]

RENEWABLE ENERGY POLICY

The National Climate Change Mitigation Plan of 2017 and the Generation Master Plan 2021–2040 both stress the importance of expanding and diversifying renewable energy. While the country produces a negligible amount of non-renewable energy, only two sources of renewable energy are developed: large hydropower and biomass. It is anticipated that diversifying into SHP and solar power will help energy stability and economic development in the country. Investments in solar photovoltaics in the western Chaco region have already begun, as well as the designation of sites for the planned SHP projects. Although the Government of Paraguay was originally interested in expanding into wind energy, various international scientific organizations found that given the topography, there is no significant potential in wind power.[13,16]

To encourage the diversification of renewable energy, the Senate passed a bill in November 2021 on Regulating the Promotion, Generation, Production, Development and Use of Electrical Energy from Non-conventional Non-hydraulic Renewable Energy Sources. The bill suggests the promotion of investment in renewable energy besides large hydropower, especially from foreign entities. It also provides the institutional framework for licensing projects above 1 MW, which the VMME would have the authority over. Additionally, it suggests financial incentives to be put in place, such as exemption from the value-added tax amongst others.[17]

ANDE was the monopoly controller of the electricity market until 2006, when Law 3009/2006 was adopted. The law opened the market to independent power producers (IPPs) to generate and transport electricity for domestic consumption or export. The law applies to all renewable energy resources with the exception of hydropower plants larger than 2 MW, in which case ANDE maintains its preferential rights.[17]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

Hydropower development projects are subject to Law 294/1993, which states that any new infrastructure development, including any hydraulic works projects, must have an environmental impact assessment approved by the Secretary of the Environment before construction.[18] Specifically regarding the water supply of a project, Law 3239/2007 on Water Resources of Paraguay requires an inventory of water resources to be carried out, as well as an approved permit for its use.[13]

COSTS OF SMALL HYDROPOWER DEVELOPMENT

With no previously existing SHP plants in Paraguay, the costs associated with developing a new project can only be estimated. The Master Generation Plan predicts an investment of approximately USD 2,500 per kW for SHP projects. The plan is to invest a total of USD 505 million to complete all 18 planned projects by 2036. The cost for the projects individually is unavailable.[13]

BARRIERS AND ENABLERS FOR 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 IPPs to enter the market;
- New policies are focused on promoting non-hydraulic sources of renewable energy.[14,16]

Some enablers to SHP development in Paraguay include:

- The untapped potential of hydropower in the country, including on smaller rivers, is significant;
- With energy stability and transmission losses being a major concern, SHP located closer to consumers could help alleviate this problem.[13]

REFERENCES

1. World Bank (2020). *Paraguay. Population, total*. Available at https://data.worldbank.org/indicator/SP.POP.TOTL?locations=PY (Accessed 28 February 2022).
2. Encyclopaedia Britannica (2018). *Paraguay*. Available at https://www.britannica.com/place/Paraguay (Accessed 28 February 2022).
3. Economic Commission of Latin America and the Caribbean (CEPAL) (2014). *La Economía del Cambio Climático en el Paraguay.* Available at https://repositorio.cepal.org/bitstream/handle/11362/37101/S1420018_es.pdf?sequence=1&isAllowed=y [in Spanish] (Accessed 28 February 2022).
4. Vice Ministry of Mines and Energy (VMME) (2021). *Electricidad - Generación* Available at https://www.ssme.gov.py/vmme/index.php?view=article&id=1216%3Aelectricidad-generacion&format=pdf&option=com_content&Itemid=603 [in Spanish] (Accessed 1 March 2022).
5. Vice Ministry of Mines and Energy (VMME) (2021). *Informe Preliminar de Energia Electrica 2020.* https://www.ssme.gov.py/vmme/pdf/balance2019/Informe%20Preliminar%20de%20Energia%20Electrica%202020.pdf [in Spanish] (Accessed 1 March 2022).
6. News of El Chaco (2021). *Bahía Negra Finalmente Tiene Conexión Eléctrica de Centrales Hidroeléctricas.* Available at https://www.abc.com.py/nacionales/chaco/2021/12/28/bahia-negra-finalmente-tiene-conexion-electrica-de-centrales-hidroelectricas/ [in Spanish] (Accessed 1 March 2022).
7. World Bank (2020). *Paraguay. Access to Electricity, rural.* Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=PY (Accessed 2 March 2022).
8. Vice Ministry of Mines and Energy (VMME) (2021). *Reseña Energética.* Available at www.ssme.gov.py/vmme/index.php?option=com_content&view=article&id=1213 (Accessed 1 March 2022).
9. National Administration of Electricity (ANDE) (2021). *Statistical Summary 2016-2020.* Available at https://www.ande.gov.py/documentos_contables/749/ande_-_statistical_summary_2016-2020.pdf (Accessed 2 March 2022).
10. National Administration of Electricity (ANDE) (2017). *Pliego de Tarifa*. Available at https://www.ande.gov.py/docs/tarifas/Pliego%20de%20Tarifas%20Nro%2021%20Version%20Actualizada%2002-11-2021.pdf (Accessed 2 March 2022).
11. Pappis, I., Centurion, C., Ramos, E.P., Howells, M., Ulloa, S., Ortigoza, E., Gardel-Sotomayor, P.E. & Alfstad, T. (2021). Implications to the electricity system of Paraguay of different demand scenarios and export prices to Brazil. *Energy Syst* 12, 911–939. Available at https://doi.org/10.1007/s12667-020-00420-w (Accessed 2 March 2022).
12. National Administration of Electricity (ANDE) (2022). *Inicia Ciclo de Entrevistas Sobre el Proyecto de Construcción de la Línea de Transmisión en 220 kV Villa Hayes-Concepción -Pozo Colorado-Loma Plata.* Available at https://www.ande.gov.py/interna.php?id=9578#.Yh-FNJ7MK3A [in Spanish] (Accessed 2 March 2022).
13. National Administration of Electricity (ANDE) (2021). *Plan Maestro de Generacion 2021-2040.* Available at https://www.energiaestrategica.com/wp-content/uploads/2021/05/PMG-2021-2040.pdf [In Spanish] (Accessed 2 March 2022).
14. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019.* United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
15. UNIDO, ICSHP (2016). *World Small Hydropower Development Report 2016.* United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
16. Secratary of the Environment (SEAM) (2017). *Plan Nacional de Mitigación al Cambio Climático, Paraguay.* Available at http://dncc.mades.gov.py/wp-content/uploads/2018/11/PLAN-NACIONAL-DE-MITIGACI%C3%93N-Y-LOS-PROGRAMAS-DE-ACCI%C3%93N.pdf in Spanish] (Accessed 3 March 2022).
17. Berkemeyer (2021). *Senado Aprueba Proyecto De Ley Relativo A Energías Renovables No Convencionales No Hidráulicas.* Available at https://www.berke.com.py/es/senado-aprueba-proyecto-de-ley-relativo-a-energias-renovables-no-convencionales-no-hidraulicas/ [in Spanish] (Accessed 3 March 2022).
18. General Directorate Directorate of Control of Envrionmental Quality and Natural Resources (DGCCARN) (n.d). *Ley 294/93 de Evaluación de Impacto Ambiental.* Available at http://mades.gov.py/sites/default/files/users/comunicacion/Ley%20294_93%20De%20Evaluaci%C3%B3n%20de%20Impacto%20Ambiental.pdf [in Spanish] (Accessed 14 March 2022).

Peru

Julio Montenegro-Gambini and Frank Charlez Ramírez Bogovich, Wasser World Ltd.

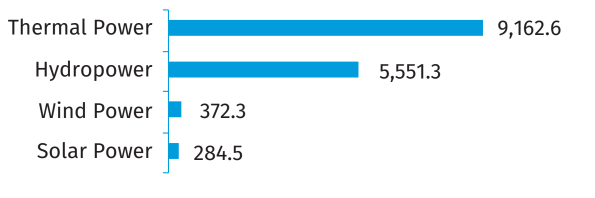
KEY FACTS

Population	32,971,846 (est. 2020)[1]
Area	1,285,215.6 km2 [2]
Topography	Peru is divided into three topographical regions: the Pacific coast, the Andean highlands (known as La Sierra) and the Amazon rainforest. Elevation ranges from 0 metres along the coast to 6,768 metres in the highlands.[3]
Climate	Peru has 28 of the world's 32 climates, a diversity created by the presence of the Andes Mountains, the cold Humboldt Current and El Niño. Temperatures vary from below 0 °C to 40 °C. Average annual temperatures are 18–20 °C on the coast, 8–11 °C in the highlands and 24 °C in the Amazon region.[3]
Climate Change	By the second half of the 21st century, climate change scenarios show an average nationwide increase in minimum temperatures of between 2 °C and 3 °C and an increase in maximum temperatures of between 4 °C and 6 °C, relative to the period 1971–2000. Precipitation is projected to increase by 10–20 per cent.[4]
Rain Pattern	Annual precipitation in Peru ranges from less than 20 mm to more than 8,000 mm. The Pacific coast is an arid region. However, during El Niño episodes the northern coast can face major flooding with precipitations higher than 4,000 mm. On the central and southern coasts, rainfall is scarce with a total range between 10 mm and 150 mm.[3]
Hydrology	The rivers of Peru are divided into three large basins: the Atlantic basin that covers almost 75 per cent of the territory of Peru and contains almost 98 per cent of the country's water resources; the Pacific basin, covering almost 22 per cent of the territory and containing approximately 2 per cent of the water resources; and the closed Lake Titicaca basin, covering less than 4 per cent of the territory and containing less than 1 per cent of the water resources. The main rivers of Peru are the Amazon, Madre de Dios, Putumayo, Napo, Maranon, Huallaga, Santa and Apurimac.[2,3]

ELECTRICITY SECTOR OVERVIEW

Total installed electricity capacity in Peru was 15,370.7 MW in 2020. Of this total, 9,162.6 MW (approximately 60 per cent) was provided by thermal power (including both renewable and non-renewable sources), 5,551.3 MW (36 per cent) by hydropower, 372.3 MW (2 per cent) by wind power and 284.4 MW (2 per cent) by solar power (Figure 1). Total available capacity the same year was 14,562.7 MW.[5]

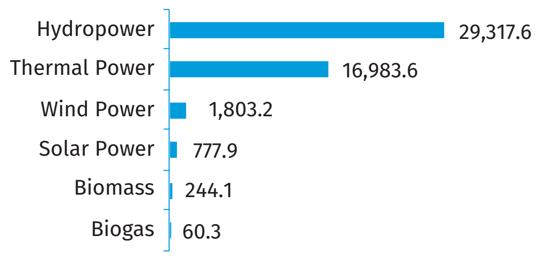
Figure 1. **Installed Electricity Capacity by Source in Peru in 2020 (MW)**



Source: OSINERGMIN[5]

Total net electricity generation in 2020 amounted to 49,186.7 GWh, representing a 7 per cent decline from 52,899.1 GWh produced in 2019. In 2020, hydropower produced 29,317.6 GWh (approximately 60 per cent of the total), thermal power 16,983.6 GWh (nearly 35 per cent) and other renewable energy sources (RES), including wind power, solar power, biogas and biomass, contributed a combined 2,885.5 GWh (6 per cent) (Figure 2).[6]

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



Source: COES[6]

The difference between installed and available capacity, as well as the low electricity generation by thermal power relative to installed capacity, is explained by the fact that significant reserve capacities of thermal power exist in Peru that are generally not utilized, as the country continues to work towards reducing its reliance on fossil fuels and prioritizing power generation from RES, including hydropower. Notably, despite an overall decrease in generation between 2019 and 2020, caused in large part by the impact of the COVID-19 pandemic, generation from RES including small hydropower (SHP) actually grew from 4,504.9 GWh in 2019 to 4,970.5 GWh in 2020, indicating a 10 per cent increase. The share of RES in annual electricity generation thus increased from 8.5 per cent in 2019 to 10.1 per cent in 2020.[6]

Access to electricity in Peru is near-universal, having improved dramatically in recent years and reaching 98 per cent in 2019.[7] The number of connected users has increased from approximately 4,879,000 in 2009 to 7,614,000 in 2019 with peak demand rising accordingly, from 4,322 MW to 7,018 MW over the same period.[5] Peak demand increased again in 2020, amounting to 7,125 MW.[6] However, the electricity grid of Peru, the National Interconnected Electric System (SEIN), has not fully kept pace with the growth of generation capacity and demand.

The key public institution overseeing activities in the energy sector of Peru is the Ministry of Energy and Mines (MINEM), which develops the legal and institutional framework for activities in the sector. Additional agencies involved in the energy sector include:

- The Supervisory Agency for Energy and Mining Investment (OSINERGMIN), which among other functions sets and regulates electricity tariffs;
- The Electrical Infrastructure Administration Enterprise (ADINELSA), a coordination agency working with local and regional authorities to provide rural electrification services; and
- The Committee for the Economic Operation of the Electric System (COES), a technical entity comprising the owners of generation plants and transmission systems, which coordinates the operation and development of the national grid (SEIN) and manages the short-term market.[8]

The electricity sector in Peru has undergone several major reforms in the last 30 years, starting with the Electricity Concessions Law of 1992, which set up a new tariff structure for end users and unbundled generation, transmission and distribution activities in the sector, allowing private entities to play a larger role. In 2006, the Law for Efficient Generation Development was adopted, aiming to guarantee efficient generation of electricity as well as to reduce the vulnerability of the electricity system to price volatility and blackouts. The law promoted longer tenders and contract terms in order to support investment in large-scale generation, implemented further tariff changes and established two new types of transmission systems—one for supplementary transmission and one for guaranteed transmission.[9] The key document outlining the ongoing and planned development of the electricity sector of Peru is the National Rural Electrification Plan 2016–2025. Among other targets, the plan aims to provide electricity access to 3.3 million people by 2025.[10] 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.[8]

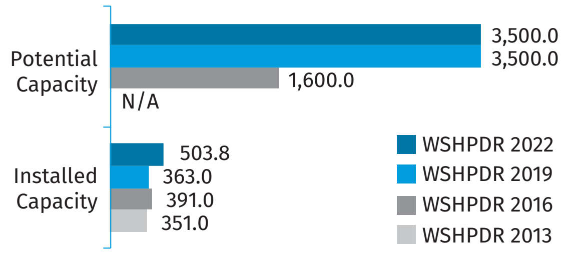
The Office for Tariff Regulation (GART), part of OSINERGMIN, regulates transmission and distribution tariffs.[8] The average tariffs have increased from 0.083 USD/kWh in 2009 to 0.103 USD/kWh in 2019.[5] Tariffs vary across economic sectors and regions.[6]

SMALL HYDROPOWER SECTOR OVERVIEW

In Peru, SHP plants are defined as hydropower plants with an installed capacity of up to 20 MW. As of 2020, there were 46 SHP plants operating in the country with a total installed capacity of 503.8 MW.[11]

In 2016, MINEM carried out an evaluation of the country's hydropower potential, identifying 380 potential SHP sites with a combined installed capacity of 3,311 MW.[12] While it is not known which of the sites identified in the study have been developed since 2016, total potential capacity for SHP in Peru, including existing plants, is estimated at 3,500 MW. This suggests that as of 2021, approximately 14 per cent of the potential capacity has been developed. Relative to the *WSHPDR 2019*, installed capacity has increased by almost 39 per cent due to the commissioning of many new SHP plants in recent years, while potential capacity has remained the same due to lack of more recent rigorous assessments (Figure 3).[9]

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

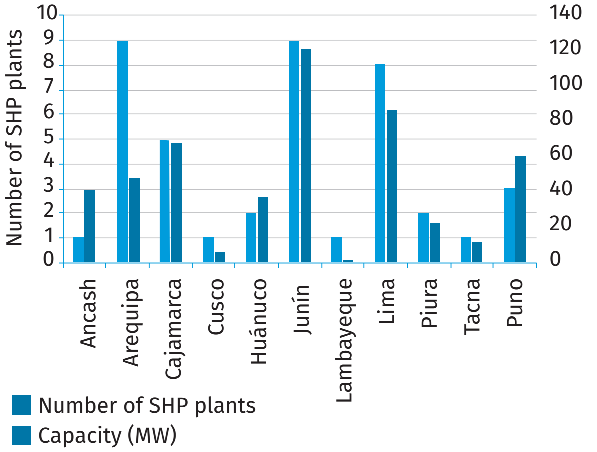


Source: OSINERGMIN,[11] *WSHPDR 2019*,[9] MINEM,[12] *WSHPDR 2013*,[13] *WSHPDR 2016*[14]

In terms of the regional distribution of SHP plants in Peru, the largest number of plants can be found in the regions of Arequipa (9 plants), Junín (9 plants) and Lima (8 plants), while the largest installed capacity of SHP is found in Junín (121.2 MW) and Lima (87 MW), which account for approximately 47 per cent of the installed capacity of SHP nationwide (Figure 4).[11] This distribution of installed capacity coincides with electricity demand, as Junín and Lima are two of the country's most heavily populated regions. A list of 20 most recently commissioned SHP plants is displayed in Table 1.

Figure 4. **Distribution of Small Hydropower Plants and**

Installed Capacity by Region in Peru



Source: OSINERGMIN[11]

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

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Operator*	*Launch year*
Purmacana	Lima - Barranca	1.8	100.0	Electrica Santa Rosa	2019
HER 1	Lima - Lima	0.7	4.5	ENEL Generación Perú	2018
Carhuac	Lima - Huarochiri	20.0	120.3	Andean Power S.A.	2018
Zaña 1	Cajamarca - San Miguel	13.2	242.0	Electro Zaña S.A.C	2018
Yarucaya	Lima - Huaura	17.5	168.9	Huaura Power Group S.A.	2017
Renovandes H1	Junín - Chanchamayo	20.0	293.7	Empresa de Generación Eléctrica Santa Ana S.R.L.	2017
Marañon	Huánuco - Huamalles	18.4	83.5	Hidroeléctrica Marañon S.R.L.	2017
Chancay	Lima - Huaral	19.2	668.2	SINERSA	2016
Rucuy	Lima - Huaral	20.0	666.0	Empresa de Generación Eléctrica Río Baños	2016
Carpapata III	Junín - Tarma	12.8	124.5	Generación Hidroeléctrica Atocongo S.A.	2016
Pátapo	Lambayeque - Chiclayo	1.0	16.5	Hydro Patapo S.A.C.	2016
Runatulo III	Junín - Concepción	20.0	419.9	Empresa de Generación Eléctrica de Junín	2014
Runatulo II	Junín - Concepción	19.1	318.5	Empresa de Generación Eléctrica de Junín	2014
Canchayllo	Junín - Jauja	5.3	85.2	Empresa de Generación Canchayllo S.A.C.	2014
Potrero	Cajamarca - San Marcos	19.9	125.4	Empresa Eléctrica Agua Azul S.A.	2014
Ángel I	Puno - Carabaya	19.9	270.0	Generadora de Energía del Perú S.A.	2014
Ángel II	Puno - Carabaya	19.9	285.0	Generadora de Energía del Perú S.A.	2014
Ángel III	Puno - Carabaya	19.9	287.0	Generadora de Energía del Perú S.A.	2014
8 de agosto	Huánuco - Huamalles	19.0	130.0	Generación Andina S.A.C.	2014
Manta	Ancash - Corongo	19.8	392.5	Peruana de inversiones en energías renovables	2013

Source: OSINERGMIN[11]

As of 2021, there were 24 ongoing SHP projects in Peru, with a total planned installed capacity of 288.5 MW. The projects all have concession contracts, with construction to be completed by 2024, but several have been delayed indefinitely and are currently undergoing further negotiations.[15,16] Several ongoing SHP projects are listed in Table 2.

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

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Developer*	*Planned launch year*	*Development stage*
Shima	San Martin - Huallaga	9.00	192.6	Energia Hidro S.A.C.	2021	Pending construction
Campanayocc	Ayacucho - Huamanga	4.62	530.0	MPJ Consulting S.A.C.	2022	In tender
Marca	Junín - Yauli	8.98	12.8	Acqua Energia	2023	Final design phase
Alcaparrosa	Junín - Yauli	9.53	11.7	Acqua Energia	2023	Final design phase
Moquegua I	Moquegua - Mariscal Nieto	15.3	538.8	EGESUR	2024	Under construction

Source: OSINERGMIN[15,16]

RENEWABLE ENERGY POLICY

Support for the development of RES in Peru was established by Legislative Decree No. 1002 for the Promotion of Investment for Electricity Generation with the use of Renewable Energy of 2008. The decree identified the development of generation of electricity from RES as a public necessity and mandated the formulation of a National Renewable Energy Development Plan, which would set a five-year rolling target share of total generation to be met by RES, excluding large and small hydropower. The subsequent plan set a 5 per cent target for generation from RES by 2013 (generation share from non-hydropower RES amounted to approximately 6 per cent in 2020).[6,8,17]

Also in 2008, the Government issued the Regulation for Electricity Generation with Renewable Energy, which determined the administrative procedures for renewable energy auctions and the granting of concessions for RES development, outlined the requirements for submitting, evaluating and awarding bids and set marketing procedures and RES tariffs.[8]

Financial and regulatory support measures for RES development include the following:

- An annual maximum accelerated depreciation of 20 per cent on income tax for all RES projects, which applies to machinery, equipment, installation, operation and maintenance work for grid-connected plants;
- Power producers using RES are entitled to early recovery of the value-added tax (VAT) from electricity sales;
- For SHP projects under 10 MW of installed capacity, permits are applied for at the regional level near the project site and no Environmental Impact Assessment (EIA) is required; instead, the developer must file a non-environmental impact commitment document.[8,9,18]

COST OF SMALL HYDROPOWER DEVELOPMENT

Previous studies concluded that a project cost of approximately 850–1,000 USD/kW is the upper limit for the market viability of SHP development in Peru, based in part on the low cost of electricity generation from the country's abundant natural gas reserves. With the generation price increased to 0.056 USD/kWh, a project cost of 1,400 USD/kW would be potentially viable.[9,19] However, most recently constructed SHP plants have exceeded these upper limits by a wide margin, with project costs ranging from 1,200 USD/kW to 4,200 USD/kW.[11]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

The primary mechanism for financing RES and other energy projects in Peru is project finance, whereby the project's revenues from operation are expected to be sufficient for repayment. The auction system for electricity generation projects provides an annual income guarantee, established by the tariff awarded on a project-by-project basis during the public auction and multiplied by the expected annual energy deliveries to the grid, with priority of dispatch and access to transmission and distribution networks likewise guaranteed. Power Purchase Agreements (PPAs) are signed for a period of 20 years.[8]

The Government of Peru has promoted the Clean Development Mechanism (CDM) first established under the Kyoto Protocol to attract international investment into the country's RES sector. In 2020, Peru and Switzerland signed a bilateral carbon offset agreement that will finance green energy development in Peru through additional levies issued by motor fuel importers in Switzerland, counting towards the latter country's virtual emissions reduction.[19,20]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

The impact of El Niño results in a great variability in the rainfall intensities in Peru, especially along the northern coast during the summer months. In 1998, extreme weather events caused by El Niño resulted in damage to the energy sector estimated at USD 166 million, of which 67 per cent corresponded to damage to hydropower infrastructure.[21] Similarly, during the coastal El Niño event of 2017, multiple hydropower plants in Peru incurred damage to their infrastructure, including the Callahuanca hydropower plant, which required two years of work and USD 45 million of investment for subsequent reconstruction.[22] With the intensity of El Niño increasing due to the ongoing global climate change, the hydropower sector in Peru can be expected to incur additional costs from related extreme weather events in the future.[23]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Peru is a country rich in RES, but only a small fraction of this potential is currently used. While investment in the renewable energy sector has been growing, the development of RES, including SHP, continues to face several obstacles, including the following:

- High initial investment costs compared to thermal power plants;
- Lack of sufficient human capacity for operation and maintenance and high cost of training;
- Limited transport and construction infrastructure impeding projects;
- Environmental concerns;
- Limited awareness in the financial sector of the RES market and profitability of RES projects, as well as project evaluation criteria and regulations. This leads to a situation where banks require external technical support to assess RES projects.

Enablers for SHP development include:

- The country's considerable untapped SHP potential;
- The experience and commitment of the country to hydropower development in general;
- Support offered in the form of long-term PPAs at guaranteed prices available for RES projects, as well as certain tax rebates.

REFERENCES

1. World Bank (n.d.). *Population, total – Peru*. Available at https://data.worldbank.org/indicator/SP.POP.TOTL?locations=PE (Accessed 27 September 2021).
2. National Water Authority (2013). *Plan Nacional de Recursos Hídricos del Perú*. Available at https://www.ana.gob.pe/sites/default/files/plannacionalrecursoshidricos2013.pdf [in Spanish] (Accessed 27 September 2021).
3. United Nations Food and Agriculture Organization (FAO) (2015). *Peru*. Aquastat database. Available at http://www.fao.org/aquastat/en/countries-and-basins/country-profiles/country/PER [in Spanish] (Accessed 27 September 2021).
4. United Nations Food and Agriculture Organization (FAO) & National Service of Meteorology and Hydrology of Peru (SENAMHI) (2014). *Regionalización Estadística de Escenarios Climáticos en El Perú*. Available at http://www.fao.org/3/bt558s/bt558s.pdf [in Spanish] (Accessed 27 September 2021).
5. Supervisory Agency for Investment in Energy and Mining (OSINERGMIN) (n.d.). *Producción, Máxima Demanda y Reserva Fría*. Available at https://observatorio.osinergmin.gob.pe/produccion [in Spanish] (Accessed 27 September 2021).
6. Economic Operation Committee of the National Interconnected System (COES SINAC) (2021). *Estadística Anual 2020.* Available at https://www.coes.org.pe/Portal/publicaciones/estadisticas/estadistica2020# [in Spanish] (Accessed 27 September 2021).
7. World Bank (n.d.). *Access to electricity (% of population) – Peru*. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=PE&view=charthttps%3A%2F%2Fyandex.ru%2F (Accessed 27 September 2021).
8. International Renewable Energy Agency (IRENA) (2014). *Renewable Readiness Assessment: Peru*. Available at https://irena.org/publications/2014/Jun/Renewables-Readiness-Assessment-Peru (Accessed 27 September 2021).
9. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
10. Ministry of Energy and Mines (MINEM) (2014). *Plan Nacional de Electrificación Rural 2016-2025*. Available at http://dger.minem.gob.pe/ArchivosDger/PNER_2016-2025/F1-PNER-2016-25.pdf [in Spanish] (Accessed 27 September 2021).
11. Supervisory Agency for Investment in Energy and Mining (OSINERGMIN) (2020). *Supervisión de Contratos de Proyectos de Generación y Transmisión de Energía Eléctrica en Operación*. Available at https://e.issuu.com/embed.html?d=compendio-proyectos-gte-operacion&u=osinergmin [in Spanish] (Accessed 30 September 2021).
12. Ministry of Energy and Mines (MINEM) (n.d.). *Portafolio de Proyectos Hidroeléctricos*. Available at http://mapas.minem.gob.pe/MAP_HIDROELECTRICO/ [in Spanish] (Accessed 30 September 2021).
13. UNIDO, ICSHP (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
14. UNIDO, ICSHP (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
15. Supervisory Agency for Investment in Energy and Mining (OSINERGMIN) (2018). *Generación Eléctrica a Ingresar al SEIN (Periodo: 2013-2023)*. Available at https://www.osinergmin.gob.pe/seccion/centro_documental/electricidad/Documentos/PROYECTOS%20GFE/Generaci%C3%B3n/Proyectos_GENERACION_proyecci%C3%B3n.pdf [in Spanish] (Accessed 30 September 2021).
16. Supervisory Agency for Investment in Energy and Mining (OSINERGMIN) (2021). *Supervisión de Contratos de Proyectos de Generación y Transmisión de Energía Eléctrica.* Available at https://e.issuu.com/embed.html?d=compendio-proyectos-gte-construccion&u=osinergmin [in Spanish] (Accessed 30 September 2021).
17. International Energy Agency (IEA) (2017). *Legislative Decree 1002 on investment promotion for generation of electricity using renewable energy of Peru*. Available at https://www.iea.org/policies/4947-legislative-decree-1002-on-investment-promotion-for-generation-of-electricity-using-renewable-energy-of-peru (Accessed 30 September 2021).
18. Ministry of Energy and Mines (MINEM) (2012). *Perú Electricity Subsector – Promotion Document*. Available at http://www.minem.gob.pe/archivos/Documento_Promotor_2012.pdf (Accessed 30 September 2021).
19. Mendiola, A., Aguirre, C., Aguilar, O., Castillo, S., Giglio, G. & Maldonado, W. (2012). *Proyectos de generación eléctrica en el Perú: ¿Centrales hidroeléctricas o centrales térmicas?* Universidad ESAN Available at https://www.esan.edu.pe/publicaciones/serie-gerencia-para-el-desarrollo/2012/proyectos-generacion-electrica-peru-centrales-hidroelectricas-termicas/ [in Spanish] (Accessed 30 September 2021).
20. Climate Home News (2020). *Peru and Switzerland sign 'world first' carbon offset deal under Paris Agreement*. Available at https://www.climatechangenews.com/2020/10/21/peru-switzerland-sign-world-first-carbon-offset-deal-paris-agreement/ (Accessed 30 September 2021).
21. Galarza, E. & Kámiche, J. (2012). *Impactos del Fenómeno El Niño (FEN) en la economía regional de Piura, Lambayeque y La Libertad*. German Agency for International Cooperation (GIZ). Available at https://www.apeseg.org.pe/wp-content/uploads/2019/02/2012_Impactos-del-FEN-en-la-economía-regional-de-Piura-Lambayeque-y-La-Libertad.pdf [in Spanish] (Accessed 30 September 2021).
22. Ministry of Energy and Mines (MINEM) (2019). *Central hidroeléctrica de Callahuanca reinicia operaciones y contribuye fortalecer el sistema eléctrico del país*. Available at https://www.gob.pe/institucion/minem/noticias/69382-central-hidroelectrica-de-callahuanca-reinicia-operaciones-y-contribuye-a-fortalecer-el-sistema-electrico-del-pais [in Spanish] (Accessed 30 September 2021).
23. Yale Environment 360 (2019). *Climate Change is Making El Niños More Intense, Study Finds*. Available at https://e360.yale.edu/digest/climate-change-is-making-el-ninos-more-intense-study-finds (Accessed 30 September 2021).

Suriname

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

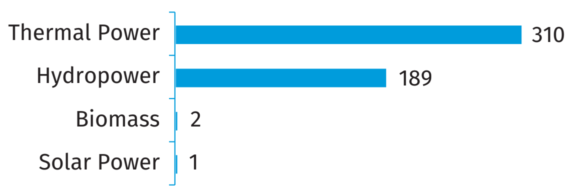
KEY FACTS

Population	586,634 (2020)[1]
Area	163,820 km²[2]
Topography	Suriname is located on the north-eastern coast of South America and the large majority of its territory is covered with tropical rainforest. The country can be divided into four ecological zones. The New Coastal Plain in the north is a flat swampland on the Atlantic coastline. Just south of this is the Old Coastal Plain, which is mostly flat but with some ridges and hills. The Wilhelmina Mountains are located in the central to southern region and has the highest altitudes. Juliana Top is the highest peak in the country at 1,230 metres. The Sipaliwini Plain is a savanna region that stretches down to the southern border with Brazil.[3]
Climate	Suriname has a tropical climate with dry and rainy seasons. Temperatures mostly remain between 21 °C and 32 °C. However, the coastal north usually only experiences the upper half of the range and the central and southern highlands experience the whole range. The driest period is between August and December, whereas the wettest season is between April and August. January to February is considered a short and minor wet season, while March to early April is a short and minor dry period.[3,4]
Climate Change	Over the past three decades, average rainfall in Suriname has shown an increase in all areas of the country and over a 500 mm per decade increase in the south-western region. However, it is predicted that by the end of the century overall rainfall will decrease, especially in the north. Temperatures have shown to increase in the northern region over the past three decades, but decrease in the south. Over the course of the next decades, average temperatures are expected to increase throughout the whole country by between 2 °C and 5 °C. Extreme weather events are also expected to increase.[4]
Rain Pattern	Rainfall varies between regions and periods of the year, but average rainfall is between 1,900 mm and 2,400 mm per year. Throughout the country, rainfall is highest between late April and early August when severely heavy rains are a common occurrence. Average rainfall in May, the wettest month, is approximately 325 mm.[3,4]
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 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. 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 approximately 60 per cent of the Coastal Plains.[5]

ELECTRICITY SECTOR OVERVIEW

In 2020, the total installed capacity of Suriname was approximately 502 MW. The country's energy mix consisted of 310 MW (just under 62 per cent) from fossil fuels, 189 MW (38 per cent) from hydropower, 2 MW from biomass and 1 MW from solar power (Figure 1).[6] The 189 MW of hydropower capacity comes from the Afobaka plant, which was originally built by and ran by Suralco, a foreign private mining company, but was given to the Government of Suriname upon the company leaving the country in 2019.[7]

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



Source: OLADE[6]

In 2020, total electricity generation was 2,368 GWh. Thermal power generated 1,252 GWh (53 per cent), hydropower generated 1,105 GWh (46 per cent) and the remaining 1 per cent comprised 9 GWh from solar power and 2 GWh from biomass (Figure 2).[6] Due to inefficient infrastructure, loss of electricity is considered an issue of concern for Suriname and in 2019 losses amounted to 452 GWh, or 19 per cent of total electricity generated.[8]

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

Source: OLADE[6]

The electrification rate in Suriname in 2019 was just under 98 per cent. More than 99 per cent of the urban population has access to electricity, whereas slightly less than 96 per cent of the rural population does.[9] In many rural areas, the most common source of energy is diesel generators, which typically only provide the communities with electricity for four to six hours per day.[10]

The two major national companies that are responsible for the generation, distribution and transmission of electricity are the State Oil Company of Suriname (Staatsolie) and the Suriname Energy Company (EBS). Originally, Staatsolie was an oil producing company and generated exclusively thermal energy, but since 2007 has sought to diversify into renewable energy with the creation of its renewable energy unit. After first diversifying into biomass in 2010, it now also generates hydropower since the transfer of control of the Afobaka hydropower plant.[11] EBS is responsible for the distribution and transmission of electricity. EBS's current major focus in improving the quality of electricity transmission and distribution infrastructures is to decrease losses and increase energy stability in the country.[10]

Table 1. **Average Electricity Tariffs by Consumer Type in Suriname**

Type of consumer	*Usage*	*Tariff (USD/kWh)*
Residential	Up to 800 kWh	0.056
	Above 800 kWh	0.087
Non-residential	Up to 2,600 kWh	0.056
	Above 2,600 kWh	0.087
Street lighting	N/A	0.079

Source: EAS[12]

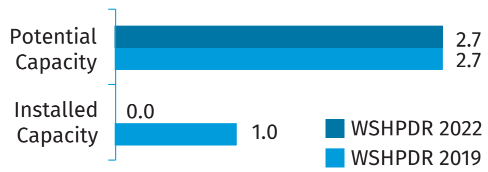
Before the implementation of the 2016 Electricity Act, the average retail electricity tariff in Suriname was 0.04 USD/kWh. This was one of the lowest tariffs in Latin America and the Caribbean and was supported by Government subsidies. In order to better regulate appropriate electricity tariffs, the Energy Authority of Suriname (EAS) was created and began operating in 2020. The details of the average tariff for each type of consumer per Decree No. 88 of 2021 are given in Table 1.[12]

SMALL HYDROPOWER SECTOR OVERVIEW

There is no official country definition for small hydropower (SHP) in Suriname. In this chapter, SHP is defined as the plants with a capacity of less than 10 MW. It is estimated that the total potential capacity of hydropower in the country is 2,419 MW.[13] Based on previously planned projects, SHP potential is at least at 2.7 MW.[14] 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 7 April 2017 and it was agreed that the Rural Small Hydro Project section would be cancelled.[15]

There have been some SHP plants that were in operation within the country in the past, but all have since closed. Poeketi was the first SHP plant constructed in Suriname. It was completed in 1981 and supplied 50 kW to the nearby community until it shut down in 1987.[16] In 2005, construction began on the Gran Olo Sula plant with the goal capacity of 300 kW, but due to flooding and financial issues, it was not completed until 2017, with a lower capacity than planned and was in operation for five days before it was shut down.[17] Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, SHP installed capacity decreased based on more accurate data, whereas the potential remained unchanged (Figure 3).

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



Sources: GEF & IADB,[14] *WSHPDR 2019*[18]

RENEWABLE ENERGY POLICY

The National Energy Plan of 2013–2033 was one of the earliest official declarations of the country's interest in expanding renewable energy. Initiatives stated in the plan include goals to bring solar power and SHP to remote areas in the southern region as well as general interest to consider wind power as a possibility to explore.[19] The Policy Development Plan 2017–2021 further stresses the importance of renewable energy and discusses the need for innovative business models to feasibly bring it into the remote interior of the country. It suggests that public-private partnerships could be a key to achieve this.[20]

In 2016, the first comprehensive energy-related legislation was enacted. The Electricity Act of 2016 set out to improve the technical and financial situation of the power sector. The aim of this act was to create an energy regulatory authority, deal with the issue of overly low electricity tariffs by recommending a reduction in subsidies, allow for privatizations and to state the importance of attracting more investment into renewable energy.[21] The act created the EAS to oversee the tariffs of the country's energy sector. The specifics of how tariffs will be calculated by the EAS were published in the subsequent Electricity Sector Plan 2019–2023.[22] The act also mandates EBS to hold renewable energy tenders under the supervision of the EAS and obligates the company to purchase all solar and wind power generated by respective plants. Furthermore, it gives consumers the possibility of generating their own electricity using a net metering system that requires that the surplus electricity generated is fed back into the national grid. This amount cannot exceed total consumption for the year.[10,21]

The Environmental Framework Act of 2020 addresses appropriate environmental management. It includes the legal framework and procedures for environmental impact assessments and created the National Environmental Authority (NMA) to oversee this. The aim of this act was to more closely align the legal framework of the country with global environmental standards and to demonstrate commitment to international agreements such as the Paris Agreement.[22]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The following barriers are particularly critical for SHP development in Suriname:

- Lack of funding, exemplified by the numerous cases of plans to develop projects being cancelled or plants being shut down soon after construction;
- Lack of local technical knowledge and skills in SHP development;
- High setup costs, in part due to the absence of road infrastructure leading to remote villages.

The following enablers may incentivize SHP development in Suriname:

- Electricity demand is continuously increasing and the installed capacity will soon have to increase to keep up;
- Over 100 villages do not have electricity for the entire day and depend on diesel generators and the monthly delivery of a finite amount of diesel to power them. SHP could greatly improve the quality of their electricity access and energy stability;
- SHP would also lessen the country's dependence on the one large hydropower plant, Afobaka.[20]

REFERENCES

1. World Bank (2020). *Population, Total – Suriname.* Available at https://data.worldbank.org/indicator/SP.POP.TOTL?locations=SR (Accessed 15 March 2022).
2. World Bank (2020). *Surface Area (Sq. Km) –– Suriname.* Available at https://data.worldbank.org/indicator/AG.SRF.TOTL.K2?locations=SR (Accessed 15 March 2022).
3. Encyclopædia Britannica (2021). *Suriname.* Available at https://www.britannica.com/place/Suriname (Accessed 15 March 2022).
4. Inter-American Development Bank (IADB) (2021). *State of the Climate Report in Suriname.* Available at https://publications.iadb.org/publications/english/document/State-of-the-Climate-Report-Suriname.pdf (Accessed 15 March 2022).
5. Food and Agriculture Organization (FAO) (2015). *Aquastat – Country Profile – Suriname.* Available at https://www.fao.org/aquastat/en/countries-and-basins/country-profiles/country/SUR (Accessed 15 March 2022).
6. Latin American Energy Organization (OLADE) (2021). *Latin America and the Caribbean Energy Outlook.* Available at https://biblioteca.olade.org/opac-tmpl/Documentos/old0442a.pdf [In Spanish] (Accessed 15 March 2022).
7. Dutch Caribbean Legal Portal (2020). *Suriname Now Owns Afobaka Hydroelectric Dam.* Available at http://www.dutchcaribbeanlegalportal.com/news/business-financial/9420-suriname-now-owns-afobaka-hydroelectric-dam (Accessed 15 March 2022).
8. Latin America and Caribbean Energy Information System–Latin American Energy Organization (sieLAC-OLADE) (2020). *Pérdidas - Electricidad.* Available at https://iadb-prod-ite-ito-external-public.s3.us-east-1.amazonaws.com/INE/Public/7.%20Perdidas%20y%20calidad/7.1%20p%C3%A9rdidas%20de%20electricidad%20y%20estimaci%C3%B3n.xlsx (Accessed 15 March 2022).
9. World Bank (2020). *Access to Electricity % – Suriname.* Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=SR (Accessed 15 March 2022).
10. Abadal Colomina, J. (2021). *Consolidating a Sustainable Energy Sector in Suriname.* IDB Blog. Available at https://blogs.iadb.org/energia/en/consolidating-a-sustainable-energy-sector-in-suriname/ (Accessed 15 March 2022).
11. Staatsolie (2021). *History.* Available at https://www.staatsolie.com/en/about-us/history/ (Accessed 15 March 2022).
12. Energy Authority of Suriname (EAS) (2021). *Staatsbesluit 2021 no 88: Elektriciteitstarieven.* Available at https://eas.sr/2021/09/12/staatsbesluit-2021-no-88-elektriciteitstarieven/ [In Dutch] (Accessed 15 March 2022)
13. Republic of Suriname (2006). *Meerjarenontwikkelingsplan 2006–2011.* Available at https://www.swris.sr/wp-content/uploads/2017/12/Meerjaren-ontwikkelingsplan.pdf [In Dutch] (Accessed 21 March 2022).
14. Global Environment Facility & Inter-American Development Bank (GEF & IADB) (2011). *Project Identification Form: Development of Renewable Energy, Energy Efficiency and Electrification of Suriname.* Available at https://publicpartnershipdata.azureedge.net/gef/PMISGEFDocuments/Climate%20Change/Suriname%20-%20(4497)%20-%20De-

velopment%20of%20Renewable%20Energy,%20Energy%20 Efficiency/8-23-2011%20ID4497%20rev%20PIF.pdf (Accessed 16 March 2022).
15. Inter-American Development Bank (IADB) (2017). *PMR Operational Report. IDB Improving Lives.* Available at http://idbdocs.iadb.org/wsdocs/getdocument.aspx-?docnum=EZSHARE-522669563-1151 (Accessed 16 March 2022).
16. van Els, R. (2012). De Puketi micro-waterkrachtcentrale in het binnenland van Suriname: implementatie, rehabilitatie en ervaringen. *Academic Journal of Suriname*, 3, 276-91. Available at https://docplayer.nl/19551249-De-puketi-mi-cro-waterkrachtcentrale-in-het-binnenland-van-surina-me-implementatie-rehabilitatie-en-ervaringen.html [in Dutch] (Accessed 16 March 2022).
17. Aboikoni, A. (2019). *Design Hydropower Plant with Indalma Turbine at the Tapawatra Fall within the Perspective of Sustainable Development.* Available at https://fga.unb.br/articles/0002/3738/MSc_RET_Thesis_Aboikoni_Andy_Fi-nal_version-151119.pdf (Accessed 16 March 2022).
18. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
19. Republic of Suriname (2015). *Intended National Determined Contribution Under UNFCCC.* Available at https://www4.unf-ccc.int/sites/submissions/INDC/Published%20Documents/Suriname/1/INDC-2-Suriname%20300915.pdf (Accessed 17 March 2022).
20. Republic of Suriname (2019). *Nationally Determined Contribution 2020*. Available at http://extwprlegs1.fao.org/docs/pdf/sur194846.pdf (Accessed 17 March 2022).
21. Grantham Research Institute of Climate Change and the Environment (2022). *Climate Change Laws of the World: Electricity Act, 2016.* Available at https://www.climate-laws.org/geographies/suriname/laws/electricity-act-2016 (Accessed 17 March 2022).
22. Starnieuws (2018). *Dikke pil leidraad voor Energie Sector Plan.* Available at https://www.starnieuws.com/index.php/welcome/index/nieuwsitem/50283 [In Dutch] (Accessed 21 March 2022).
23. Food and Agriculture Organization (FAO) (2020). *Suriname: Environmental Framework Act.* Available at https://www.fao.org/faolex/results/details/es/c/LEX-FAOC199141 (Accessed 18 March 2022).

Uruguay

Cecilia Correa Poseiro and Arturo Alarcón, Inter-American Development Bank

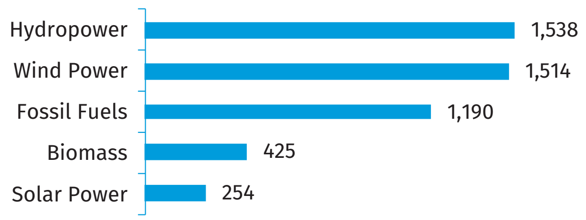
KEY FACTS

Population	3,473,727 (2020)[1]
Area	176,215 km²[2]
Topography	Uruguay has a low and slightly sloping topography with an average elevation of 116.7 metres above sea level. The relief is homogeneous, with two large structural areas: peneplains and plains. The peneplains are gently undulating reliefs that extend over most of the country's territory and contain rounded hills with a wide base, which are known as cuchillas and reach a maximum height of 514 metres. The plains extend in the peripheral areas of the Uruguay River, the River Plate and the Atlantic Ocean.[2,3]
Climate	Throughout its entire territory Uruguay has a homogeneous climate characterized as a temperate-humid one without a dry season. The average annual temperature is 17.5 °C, with a maximum average of 19 °C in the north and 16 °C on the Atlantic coast. The average temperature in winter is 11.5 °C and in summer 23.9 °C. The minimum temperatures occur in winter, generally in July; and the maximum temperatures occur in summer, generally in January.[3,4,5]
Climate Change	The average annual temperature is showing an increasing trend. The year 2017 was one of the warmest years on record with an average temperature of 18.7 °C, a maximum average of 24.1 °C and a minimum average of 13.2 °C.[6] Studies have also detected an increase in average precipitation between 1961 and 2017 with an average increase of 10 per cent in the north of the country and 15–20 per cent in the south.[7]
Rain Pattern	Average annual rainfall is approximately 1,300–1,400 mm. Precipitation demonstrates considerable annual variability with a minimum average of 900 mm recorded in 1989 and a maximum average of 2,100 mm recorded in 2002, according to the statistical period of 1980–2009.[6] On average, precipitation is equally distributed across the four seasons of the year (300–350 mm in each season).[7] The phenomena that affect the rainfall patterns in Uruguay the most are the Niño-Southern Oscillation, which increases precipitation probability, and La Niña, which generates prolonged and deep droughts. Both phenomena could become more frequent with an increase in the average global temperature.[8]
Hydrology	The main water basins in the country are the Uruguay River in the west, the River Plate in the south-west, the Black River in the centre of the country, the Santa Lucia River in the south, the Atlantic Ocean in the south-east and the Merin Lagoon in the centre-east. The Uruguay River (100,000 km² basin in Uruguay), the River Plate, the Black River and the Santa Lucia River belong to the main basin of the River Plate.[9] The River Plate Basin has a total area of 3,100,000 km², making it the fifth largest in the world, and covers five countries: Argentina, Bolivia, Brazil, Paraguay and Uruguay.[10] The Merin Lagoon and the basin of the Atlantic Ocean pour directly into the Atlantic Ocean.[11]

ELECTRICITY SECTOR OVERVIEW

In 2019, the installed electricity capacity of Uruguay stood at 4,920 MW. Of the total, 31 per cent came from hydropower, 31 per cent from wind power, 9 per cent from biomass, 5 per cent from solar photovoltaics (PV) and the remaining 24 per cent from fossil fuel thermal plants (Figure 1).[12] The installed capacity increased by 80 per cent in the last 10 years (compared to 2,690 MW in 2010), mainly due to the installation of 1,473 MW of wind power capacity, 253 MW of solar power and 540 MW of thermal power (combined cycle).[12]

Figure 1. **Installed Electricity Capacity by Source in Uruguay in 2019 (MW)**

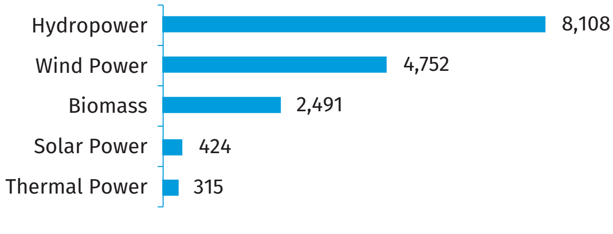


Source: MIEM[12]

Most of the hydropower potential in Uruguay (estimated at 1.8 GW), has been utilized, making it the country with the highest hydropower potential utilization rate in the region (85 per cent).[13] Of the 1,538 MW of the total installed hydropower capacity, 108 MW correspond to the Baygorria hydropower plant, 152 MW to Gabriel Terra, 333 MW to Constitucion and 945 MW to Salto Grande (50 per cent of the plant's capacity of 1,890 MW belong to Uruguay).[14]

Electricity generation in 2019 amounted to 16,088 GWh, of which 50 per cent was from hydropower, 30 per cent from wind power, 15 per cent from biomass, 3 per cent solar power and 2 per cent fossil fuel thermal power (Figure 2).[12] The maximum demand was 11,023 GWh and the maximum power was 2,121 MW. Electricity consumption per capita in 2019 stood at 3.22 MWh and has showed an average annual growth of 2 per cent over the last decade. The electrification rate in the country is 99.8 per cent, with 99.9 per cent in urban areas and 98.9 per cent in rural areas.[12]

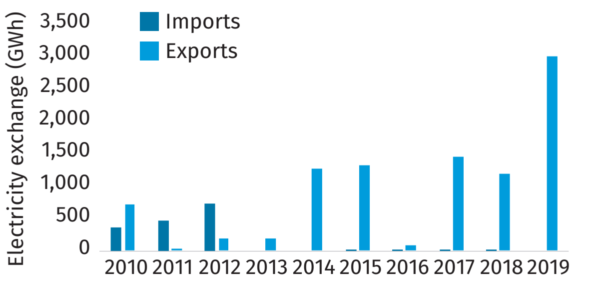
Figure 2. **Annual Electricity Generation by Source in Uruguay in 2019 (GWh)**



Source: MIEM[12]

The electricity system of Uruguay is interconnected with that of Argentina via the 132/150 kV Concepción-Paysandú interconnection of 100 MW and the 500 kV Salto Grande transmission quadrilateral, which is composed of the 1,890 MW Salto Grande interconnection line and the 1,386 MW Colonia Elía-San Javier interconnection line. Uruguay is also connected to the electricity system of Brazil via two 50Hz/60Hz frequency converters: Santa Ana de Livramento with a capacity of 70 MW and the Melo converter with a capacity of 500 MW. From 2013 to 2019, Uruguay was a net exporter of electricity (Figure 3).[15] In 2019, the country exported 3,012 GWh of electricity (80 per cent to Argentina and 20 per cent to Brazil).[16]

Figure 3. **Electricity Exports and Imports of Uruguay in 2010–2019 (GWh)**



Source: MIEM[15]

The electricity transmission system of Uruguay is composed of 5,790 kilometres of high-voltage lines (500 kV, 230 kV, 150 kV and 60 kV). The electricity distribution system consists of 4,960 kilometres of 60 kV and 30 kV lines; 53,097 kilometres of 22 kV, 15 kV and 6 kV lines; and 28,178 kilometres of 230 V and 400 V lines. There are 3,902 medium-voltage substations and 4,684 medium-voltage/low-voltage substations.[16]

The electricity mix of Uruguay has undergone a significant transformation over the last 10 years. Until 2007, it was mainly composed of hydropower and thermal power generation from fossil fuels. This created high dependence on rain patterns, electricity exchanges with the neighbouring countries and fuel imports. In 2007, Uruguay incorporated a significant proportion of biomass into its electricity mix, while the first wind farm in the country began to operate in 2009. Already in 2017 the country's mix of electricity sources was highly diversified, with more than 1,500 MW of wind power capacity, 420 MW of biomass and 240 MW of solar power. The clear regulatory framework, tax incentives for the private sector and financial innovation that increased the bankability of the projects were key for this transformation.[17]

Currently, there are 43 wind farms that generate and sell electricity to the public electric utility the National Administration of Power Plants and Electrical Transmissions (UTE) through power purchase agreements (PPA). Of these, 38 are fully privately owned under a public-private partnership (PPP).[17] The financial models of these projects vary: three wind farms were fully publicly financed, four received partial public financing (from 6 per cent to 50 per cent), 40 were fully privately financed and three are owned by UTE. For the last group of projects UTE emitted fixed-rate bonds and shares to finance between 10 per cent and 24 per cent of each project.[17]

The electricity sector of Uruguay is governed by Law 18.632/97 New Regulatory Framework for the Electricity Sector. The sector is regulated by the Energy and Water Services Regulation Unit (URSEA), which was assigned greater control competence by the 2020 Emergency Consideration Law (Law 19889), and the National Energy Directorate under the Ministry of Industry, Energy and Mining (MIEM). The entity in charge of planning and operating the electricity system is the Electricity Market Administration (ADME).

The public electricity utility UTE is a decentralized and vertically integrated state agency founded in 1912 and governed by an Organic Law (Law 15,031/80). The responsibility of UTE is to guarantee the sustainably of electricity service provision to its 1,512 million customers (2019).[16] UTE owns generation assets and has a monopoly on electricity transmission and distribution in the country. In the generation subsector, UTE participates with approximately 38 per cent of the system's installed capacity and an additional 7 per cent as a co-owner. Furthermore, the Salto Grande binational hydropower project accounts for 19 per cent of the total installed capacity, while the rest is owned by the private sector.[16] Private parties are free to participate in the generation sector and can either sell their electricity on the spot market or sign PPAs with the electric company. The generation units of UTE are dispatched according to their marginal cost.

Electricity tariffs are proposed by UTE and approved by the Government with the authorization (not binding) of URSEA and the Office of Planning and Budget (Law 16.832). URSEA is responsible for calculating the technical reference fee. There are several types of residential tariffs: simple residential, basic residential, general simple, double hour, triple hour and general seasonal hour (Table 1).[18] The double hour, triple hour and general seasonal hour tariff categories were established to encourage greater demand management and system efficiency. There are also several energy efficiency programmes that have an impact on the affordability of the electricity services. In addition, there are various tariffs for medium- and large-scale consumers.

Table 1. **Residential Electricity Prices by Category in Uruguay in 2021**

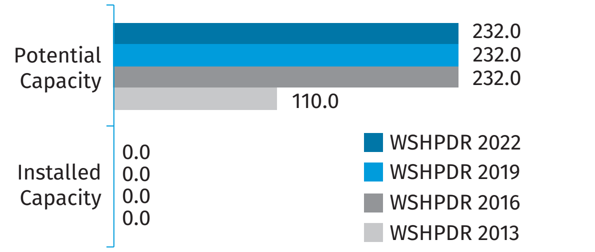
Tariff category	*Price (USD)*		*Description*
	Fixed charge	*Variable per kWh*	
Residential simple	5.42 + 1.68 per kW of power contracted	0.14	Consumption of 1–100 kWh per month
		0.18	Consumption of 101–600 kWh per month
		0.22	Consumption > 601 kWh per month
Residential double schedule	9.78 + 1.68 per kW of power contracted	0.23	Peak hours: 4 consecutive hours between 17:00 and 23:00
		0.09	Off-peak hours (Saturday, Sundays, holidays)
Residential triple schedule	9.78 + 1.68 per kW of power contracted	0.23	Peak hours: 4 consecutive hours between 17:00 and 23:00
		0.12	Shoulder hours: rest of the hours
		0.05	Valley hours: 0:00 to 7:00
Residential basic	8.79	0.18	Consumption of 101–140 kWh per month
		0.33	Consumption of 141–350 kWh per month
		0.22	Consumption > 351 kWh per month

Source: UTE[18]

SMALL HYDROPOWER SECTOR OVERVIEW

In Uruguay, small hydropower (SHP) plants are defined as hydropower plants with an installed capacity between 1 MW and 50 MW. Pico-hydropower is defined as less than 5 kW, micro-hydropower as between 5 kW and 100 kW and mini-hydropower as between 100 kW and 1 MW.[19] Currently, in Uruguay there are no hydropower plants in operation of less than 50 MW of capacity. Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, both the installed and potential capacity have remained unchanged (Figure 4).

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



Source: Schenzer et al.,[19] *WSHPDR 2013*,[20] *WSHPDR 2016*,[21] *WSHPDR 2019*[22]

Note: Data for SHP up to 50 MW.

Within the framework of the Energy Policy 2005–2030, in 2006 UTE opened a tendering process for PPAs for up to 60 MW of renewable energy capacity from wind power, biomass and SHP (Decree 77/006). The objective was to award 20 MW per technology on an equitable basis. However, although UTE received bids that exceeded the target for the first two technologies, no bids were received for SHP. Following this situation, no new initiatives have been undertaken by the Government for new SHP projects.[23]

In terms of potential SHP projects for generation only, a study developed by the University of the Republic of Uruguay (UDELAR) identified 70 potential sites for a total capacity of 231.5 MW and an annual generation of 1,431 GWh. At each of the identified sites, at least 1 MW of capacity could be installed without affecting protected areas, population centres or major communication routes. Of the identified sites, two are over 10 MW (12.8 MW and 10.7 MW) and the rest are of less than 10 MW. The study selected five of the 70 potential sites to evaluate potential capacity, generation, environmental impact and economic and financial feasibility. Of these, four demonstrated to be economically feasible (Table 2).[19]

Table 2. **List of Selected Potential Small Hydropower Sites in Uruguay**

Name	*Potential capacity (MW)*	*Capacity factor (%)*	*Estimated annual generation (GWh)*
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: Schenzer et al.,[19] *WSHPDR 2016*[21]

Note: Based on data from 2013.

UDELAR also carried out a study of 913 dams existing in the country to assess the possibility of developing new SHP plants on them and making them multipurpose.[24] As a result, 20 existing dams with the highest generation potential were selected for a pre-feasibility analysis. Considering a continuous irrigation scenario, the annual generation of the projects would vary between 60 MWh and 1,700 MWh with a mean of 380 MWh. Only 14 projects have a positive Internal Rate of Return (IRR), with an average IRR of 4.65 per cent and a maximum of 8.8 per cent. The continuous irrigation scenario is estimated to be the most beneficial one in terms of the IRR.[24]

Additionally, UDELAR undertook a pre-feasibility analysis of 17 most promising new multipurpose dams with irrigation as the priority activity and hydropower generation as secondary.[24] The power range of these dams was estimated at 11–569 kW with a mean of 130 kW for continuous irrigation and at 34–1,706 kW with a mean of 385 kW if used with intermittent irrigation. According to the study, there are 14 cases with a positive IRR, ranging from 0.3 per cent to 8.8 per cent, with a mean of 3.3 per cent, when considering continuous irrigation. There are six cases with a positive IRR ranging from 0.7 per cent to 6.7 per cent with a mean of 1 per cent when considering intermittent irrigation.[24] These studies provide a solid foundation for the development of SHP projects in Uruguay, both on new and existing dams. Nonetheless, as mentioned in the document, the sector has been more interested in developing other renewable energy sources in recent years.

RENEWABLE ENERGY POLICY

In 2008, the Government of Uruguay approved the Energy Policy 2005–2030 based on four axes: institutional, supply, demand and social. For each of the axes, the policy set general and specific objectives. With regard to supply, it established specific goals for 2015, including the contribution of domestic renewable energy sources to the country's primary energy mix as well as a 15 per cent share of non-conventional renewable sources (wind power, biomass waste, micro-hydropower) in the country's electricity generation.[25] This goal has been achieved, with electricity generation from non-conventional renewable sources having surpassed 20 per cent already in 2014.[12] The Energy Policy was endorsed by all political parties with parliamentary representation, which provided clarity and certainty to private actors. Furthermore, as of the moment of writing of this chapter the Government was working on the design of the Energy Policy 2020–2050, which was expected to be issued in 2021.

Internationally, Uruguay ratified the Paris Agreement and submitted its Nationally Determined Contributions (NDCs) in 2017, setting specific mitigation measures for the energy sector.[26] These include targets for the wind power, solar power and biomass total installed capacity, which have already been exceeded by 104 per cent, 110 per cent and 110 per cent, respectively.[27] Uruguay has also announced its commitment to prepare and present a long-term strategy for low greenhouse gas emissions development, to increase adaptation to the climate crisis and promote weather resilience.[28] One of the commitments includes an aspirational goal of reaching net zero CO_2 emissions by 2050. The long-term strategy will be aligned with the National Policy of Climate Change of 2017.

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

Within the framework of the National Water Policy (Law 18,610), Decree 205/017 approved the National Water Plan. It establishes several programmes and projects for integrated water management. These are focused on sustainability and risk control, development of management plans and information and capacity building systems. The plan also establishes the importance of large-scale hydropower but recognizes that there is no potential for additional new large- and medium-scale projects. Additional hydropower capacity may come from the modernization and repowering of existing large-scale plants or smaller-scale projects. Ultimately, the plan recognizes that viable SHP projects are those resulting from new or existing multipurpose reservoirs. For multipurpose dams with potential capacity of less than 10 MW (irrigation and generation), irrigation is to remain the priority water use.[29]

Law 16466 (Environmental Impact Assessment Law) establishes that for the construction or modernization of any power plant of more than 10 MW of any kind, including SHP plants, an environmental impact assessment (EIA) must be carried out. EIAs are also required for the construction of dams with a reservoir capacity greater than 2 million m^3 or whose water mirror exceeds 100 hectares and with water intakes with a flow greater than 500 litres per second.[30]

Furthermore, Decree 173/010 regulates bidirectional electricity exchange with the distribution network for micro-generators. It allows subscribers to generate electricity for self-consumption and to inject the surplus into the distribution network if the maximum current generated in low voltage does not exceed 16 A or 25 A for single-wire ground return.[31]

Finally, a range of investment promotion policies also apply to potential SHP projects. Thus, Law 16906 on Investments and Industrial Promotion declares of national interest the promotion and protection of investments made in the national territory. It provides important incentives and tax benefits to companies that make investments. In particular, Decree 354/009 declares of national interest the investments in projects of domestic and renewable energy generation, including SHP. Such projects will receive the benefits established by Law 16906. According to Decree 354/009 and then Decree 2/012, Decree 143/018 and Decree 268/020, projects score in various defined policy areas and according to the final score companies can exempt a percentage of the value of the investment project in taxes.[32,33,34]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The main barriers to the implementation of SHP projects in Uruguay include the following:

- The annual variability of rainfall in the country is greater than the annual variability of wind and sun. The average solar and wind power generation in a quarter will be similar to any other quarter in the same historical series. However, to find two similar hydraulic years in terms of average production, a 20-year moving window should be used.[35] The variability of hydrological conditions therefore implies an additional risk for SHP developers compared to wind or solar energy.
- High transactional costs for projects that require new dams and reservoirs due to the need to obtain several approvals with different agencies (National Energy Directorate, National Water Directorate, Ministry of Environment, General Directorate of General Resources, UTE, etc.) and the lack of experience in the processing of this kind of projects.[36]
- Higher investment costs compared to other non-conventional renewable energy technologies such as wind and solar power, which have seen a significant cost reduction in recent years.[36]
- The small scale of potential projects and the difficulty of standardization affect the interest of suppliers to participate and the chances of obtaining competitive prices.
- There are socio-environmental restrictions for the construction of projects involving the development of new reservoirs or dams.
- High perceived risk of hydropower development, compared with other non-conventional renewable energy projects such as wind and solar power, which affects investment conditions.
- Limited tariff incentives that remunerate all the services that SHP plants can provide, such as peaking power, for instance.
- Limited experience and knowledge of the different stages of SHP projects (planning, implementation, operation, and maintenance).[22]

In spite of the listed barriers, opportunities for SHP development in Uruguay exist, in particular taking into account the following factors:

- Availability of untapped SHP potential and data on sites suitable for development;
- The policy framework favouring the exploitation of domestic renewable energy technologies, including SHP.

Further initiatives that could be considered to support the implementation of SHP projects in the country could include:

- Review of the regulatory framework to allow appropriate retribution to all services that SHP can provide;
- Development of guidelines to facilitate and/or clarify permitting processes;
- Promotion of the development of SHP on already built multipurpose projects where significant investments on civil works are already done;
- Promotion of knowledge of SHP development; and
- Development of financial mechanisms that allow absorbing or dampening differences in earnings due to annual rainfall variability (i.e., revolving funds, insurances).

REFERENCES

1. World Bank (2020). *Population, total — Uruguay.* Available at https://data.worldbank.org/indicator/SP.POP.TOTL?locations=UY (Accessed 13 September 2021).
2. National Institute of Statistics (INE) (2003). *Uruguay en cifras*. Available at https://www.ine.gub.uy/documents/10181/39317/Uruguay+en+Cifras+-+2003.pdf/b0e55ada-096c-4a18-a002-5f7f9f7550f5 (Accessed 28 December 2020).
3. Romero R. (n.d). *Características Geográficas y Socioeconómicas del Uruguay.* Available at http://www.inia.org.uy/disciplinas/agroclima/uruguay_gral.htm (Accessed 28 December 2020).
4. Uruguayan Institute of Meteorology (Inumet) (n.d). *Estadísticas Climatológicas*. Available at https://www.inumet.gub.uy/clima/estadisticas-climatologicas (Accessed 28 December 2020).
5. World Bank Group (2020). *Climate Data — Uruguay.* Available at https://climateknowledgeportal.worldbank.org/country/uruguay/climate-data-historical# (Accessed 28 December 2020).
6. Lorenzo, I., Zilli, C., Martínez, G., Sena, V & Penengo, C. (2019). *Tercer Informe Bienal de Actualización a las Conferencia de las Partes en la Convención Marco de las Naciones Unidas sobre el Cambio Climático.* Ministerio de Vivienda, Ordenamiento Territorial y Medio Ambiente. Available at https://www4.unfccc.int/sites/SubmissionsStaging/NationalReports/Documents/514082697_Uruguay-BUR3-1-20191231%20URUGUAY%20BUR3%20ESP.pdf (Accessed 28 December 2020).
7. Barreiro, M., Arizmendi, F. & Trinchin, R. (2019). *Variabilidad observada del clima de Uruguay.* Departamento de Ciencias de la Atmósfera, Instituto de física, Facultad de Ciencias. Available at https://www.dinama.gub.uy/oan/documentos/Producto-2.pdf (Accessed 6 January 2021).
8. Ministry of Housing, Land Management and Environment (MVOTMA) & National System of Response to Climate Change and Variability (SNRCC) (2020). *Plan Nacional de Adaptación al Cambio Climático de la Zona Costera de Uruguay.* Montevideo.
9. Administrative Commission of the Uruguay River (n.d). *El Río Uruguay en Cifras.* Available at https://www.caru.org.uy/web/acerca-de/prueba-pagina/ (Accessed 8 January 2021).
10. Department of Sustainable Development, Organization of American States. (2006). *Cuenca del Plata en Números.* Available at https://www.oas.org/DSD/plata/numerosf.htm (Accessed 8 January 2021).

11. Velasco, H. G. (2003). *Administración de Derechos de Agua: Experiencias, asuntos relevantes y lineamientos (No. 81)*. Rome: Food and Agriculture Organization.
12. Ministry of Industry, Energy and Mining (MIEM) (2020). *Balance Energético Nacional*. Available at https://ben.miem.gub.uy/ (Accessed 28 December 2020).
13. Alarcón, A. D. (2018). *El Sector hidroeléctrico en Latinoamérica: Desarrollo, potencial y perspectivas.* Washington D.C.: Banco Interamericano de Desarrollo.
14. Salto Grande (2020). *Official website*. Available at https://www.saltogrande.org/ (Accessed 8 January 2021).
15. Ministry of Industry, Energy and Mining (MIEM) (2019). *Energy Balance 2019: Historical Series 1965–2019*. Available at https://ben.miem.gub.uy/descargas/10anteriores/BEN2019-libro.pdf (Accessed 12 September 2021).
16. National Administration of Power Plants and Electrical Transmissions (UTE) (2020). *Cifras 2019.* Available at https://portal.ute.com.uy/institucional/informacion-economico-financiera/ute-en-cifras (Accessed on 8 January 2021).
17. Suárez, A., Yitani, J., Astesiano, G., Valencia, A., Correa, C. & Corzo, J. (2020). *Casos de estudio en Asociaciones Público-Privadas en América Latina y el Caribe. Generación de Electricidad con Fuentes Eólicas en Uruguay.* Washington D.C.: Banco Interamericano de Desarrollo.
18. National Administration of Power Plants and Electrical Transmissions (UTE) (2020). *Pliego Tarifario.* Available at https://portal.ute.com.uy/sites/default/files/docs/Pliego%20Tarifario%20Vigente.pdf (Accessed 28 December 2020).
19. Schenzer, D., Chretie,s C., Pienika, R., Rovira, L. & Teixeira, L. (2013). *Generación Hidroeléctrica en pequeña escala.* Available at https://www.gub.uy/ministerio-industria-energia-mineria/comunicacion/publicaciones/generacion-hidroelectrica-pequena-escala (Accessed 29 December 2020).
20. UNIDO, ICSHP (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
21. UNIDO, ICSHP (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
22. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
23. Office of Planning and Budget (2019). *Presente y futuro de las energía renovables en Uruguay.* Montevideo: Office of Planning and Budget.
24. Terra, R. & Schenzer, D. (2013). *Factibilidad de pequeñas centrales hidroeléctricas multipróposito en presas ya construidas.* Available at https://www.gub.uy/ministerio-industria-energia-mineria/comunicacion/publicaciones/factibilidad-pequenas-centrales-hidroelectricas-multiproposito-presas-ya (Accessed 23 December 2020).
25. Ministry of Industry, Energy and Mining (MIEM) (2008). *Energy Policy 2005–2030.* Available at http://www.eficienciaenergetica.gub.uy/documents/20182/22528/Pol%C3%ADtica+Energ%C3%A9tica+2005-2030/841defd5-0b57-43fc-be56-94342af619a0 (Accessed 28 December 2020).
26. Oriental Republic of Uruguay (2017). *Primera Contribución Determinada a Nivel Nacional al Acuerdo de París*. Available at https://www.gub.uy/ministerio-ambiente/sites/ministerio-ambiente/files/documentos/publicaciones/Uruguay_Primera_Contribucion_Determinada_a_nivel_Nacional%20%285%29.pdf (Accessed on 28 June 2021).
27. National System of Response to Climate Change and Variability (SNRCC) (n.d.). *Sistema de programación, medición, reporte y verificación de la Política Nacional de Cambio Climático (PNCC) y la Contribución Determinada a nivel Nacional (CDN)*. Available at http://monitorcdn.mvotma.gub.uy/medidas-mitigacion (Accessed 17 February 2021).
28. Ministry of Environment (2020). *Estrategia de Largo Plazo de Uruguay para un Desarrollo Bajo en Emisiones y Resiliente al Clima*. Available at https://www.gub.uy/ministerio-ambiente/politicas-y-gestion/estrategia-largo-plazo-uruguay-para-desarrollo-bajo-emisiones-resiliente-clima (Accessed 17 February 2021).
29. Ministry of Housing, Land Management and Environment (MVOTMA) (2017). *Plan Nacional de Aguas*. Available at https://www.gub.uy/ministerio-ambiente/politicas-y-gestion/planes/plan-nacional-aguas (Accessed 2 December 2020).
30. Official Information Centre (IMPO) (1994). *Ley de evaluacion del impacto ambiental*. Available at https://www.impo.com.uy/bases/leyes/16466-1994 (Accessed on 28 June 2021).
31. Official Information Centre (IMPO) (2010). *Autorizacion a suscritores conectados a la red de distribucion de baja tension a instalar generaciones de fuentes renovables*. Available at https://www.impo.com.uy/bases/decretos/173-2010/2 (Accessed on 28 June 2021).
32. Official Information Centre (IMPO) (2012). *Reglamentacion de la Metodologia de Evaluacion de los Proyectos de Inversion*. Available at https://www.impo.com.uy/bases/decretos/2-2012 (Accessed on 27 June 2021).
33. Official Information Centre (IMPO) (2018). *Reglamentacion de los arts. 15 a 17-ter de la ley 16.906 (ley de inversiones y promocion industrial)*. Available at https://www.impo.com.uy/bases/decretos/143-2018 (Accessed on 27 June 2021).
34. Official Information Centre (IMPO) (2020). *Reglamentacion de los arts. 11 a 19 de la ley 16.906 (ley de inversiones y promocion industrial)*. Available at https://www.impo.com.uy/bases/decretos/268-2020/8 (Accessed on 27 June 2021).
35. Di Chiara, L., Nogales, A., Sanin, M., Tejeda, J. & Hallack, M. (2019). *La complementariedad de la generación hidroeléctrica con las energías renovables no convencionales y la importancia de la integración regional. La experiencia de Uruguay.* Banco Interamericano de Desarrollo. Available at https://publications.iadb.org (Accessed on 27 June 2021).
36. Terra, R. & Schenzer, D. (2014). *Barreras para la implementación de pequeñas centrales hidroeléctricas.* Available at https://www.gub.uy/ministerio-industria-energia-mineria/comunicacion/publicaciones/publicaciones-sobre-pequenas-centrales-hidroelectricas-pch (Accessed on 27 June 2021).

Venezuela

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

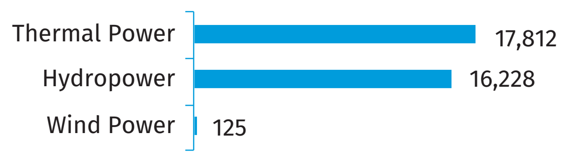
KEY FACTS

Population	28,435,943[1]
Area	912,050 km^2 [2]
Topography	The topography of Venezuela is very diverse and includes lowland plains, forested highlands and mountain ranges. The coastal areas to the north are largely plains with a small coastal mountain range near the centre. North-east near the border with Guyana are swampy lowlands centred in the Orinoco Delta. The Andes Mountain Range extends from Colombia into western Venezuela and is the region of the highest altitudes. The highest point is Bolivar Peak, which rises to 4,978 metres. The highlands of the central and southern regions are mostly hills and plateaus covered with jungles and is where Angel Falls, the world's highest uninterrupted waterfall at 979 metres, is located.[3]
Climate	Venezuela has a mild tropical climate, with little variation of temperature in a given region throughout the year. Coastal regions are generally warm and have average temperatures between 22 °C and 28 °C. The lowest temperatures can be found in the Andean Mountain region where it can reach below 8 °C. The wet season for the country is between May and November and the dry season is between December and April.[3]
Climate Change	Climate change has already begun affecting Venezuela and is expected to worsen. Due to rising temperatures, four out of the five glaciers in the country have melted since 1990. By the end of the century, temperatures are expected to increase by between 1 °C and 3.5 °C. Additionally, the recent surge in droughts is expected to become more severe, which will affect water availability throughout the country. Average rainfall is projected to decrease by between 35 mm and 110 mm per annum by 2100.[4,5]
Rain Pattern	Rain patterns vary considerably across regions in Venezuela. The north-western costal region is the driest, with some parts only receiving 280 mm per year. The wettest region is the south-eastern rain forest, where annual precipitation usually exceeds 2,000 mm.[3,6]
Hydrology	The country has rich water resources featuring more than 1,000 rivers. The Orinoco River is the eighth largest in the world and one of the most important rivers in Venezuela. It begins in the southern highlands and does many turns before draining in the Atlantic Ocean through a delta spanning more than 440 kilometres of coastline. Some of the major tributaries are the Caroní, Apure and Meta Rivers. The Orinoco also has a southern branch that flows into the Negro River, a tributary to the Amazon. Lake Maracaibo, in the west, is the largest lake in South America and is fed from the south by 10 rivers and flows into a channel that leads to the Gulf of Venezuela to the north.[3,7]

ELECTRICITY SECTOR OVERVIEW

In 2019, the total installed capacity in Venezuela was 34,165 MW. Of that, 17,812 MW, or approximately 52 per cent, was from thermal power plants, while hydropower accounted for slightly over 47 per cent of the energy mix with 16,228 MW. The installed capacity of wind power plants was 125 MW (Figure 1).[8] However, due to deteriorating infrastructure and institutional hindrances, approximately 75 per cent of the installed capacity is not in operation. In 2019, the total available capacity was approximately 8,565 MW, of which 6,393 MW was from hydropower, 2,162 MW from thermal power and 10 MW from wind power. The single most important power plant in Venezuela is the Simon Bolivar hydropower plant, which has an installed capacity of over 10,000 MW and is the source of electricity for more than 60 per cent of the population. However, the same as most power plants in the country, it has not been able to provide its full installed capacity in recent years.[9]

Figure 1. **Installed Electricity Capacity by Source in Venezuela in 2019 (MW)**



Source: AVIEM[8]

Total electricity production was approximately 109,000 GWh in 2018.[10] More recent data on generation is currently unavailable. In comparison to 2016, electricity generation decreased by roughly 6 per cent. Access to electricity reached 100 per cent in 2019. However, the electricity system in the country lacks reliability, with blackouts occurring on a daily basis. Venezuela is undergoing an electricity crisis, as the situation has not improved in many years, and much of the population is forced to ration their usage.[9]

Under Law 5.330 passed in 2007, the 14 companies that handled the generation, distribution and transmission of electricity were unified into one state-owned company, the National Electricity Company (CORPOELEC). In 2009, the Ministry of Popular Power of Electric Energy (MPPEE) was created to be in charge of regulation, monitoring and evaluation of activities in the electricity sector.[11] Since creation, both CORPOELEC and MPPEE have experienced institutional declines, largely because of widespread corruption and deprofessionalization of the sector. Between the years 2013 and 2018, almost 50 per cent of the employees of CORPOELEC moved out of the country, leaving the company understaffed and the labour market without energy-related skills.[9] The monthly electricity reports of CORPOELEC were discontinued in 2009 and the annual management report of the MPPEE has not been disclosed since 2014.[12] Therefore, obtaining official, up-to-date information on the electricity sector is a challenge.

Electricity tariffs in Venezuela are constantly changing due to supply issues and high inflation, and are therefore difficult to determine. For example, some citizens have reported experiencing up to 3,000 per cent increase in electricity tariffs between 2020 and 2021.[13]

SMALL HYDROPOWER SECTOR OVERVIEW

There is no specific definition for small hydropower (SHP) in Venezuela, therefore, this chapter will refer to SHP as plants of up to 10 MW. There are seven SHP plants in Venezuela, all of them below 1 MW. The total installed capacity is at least 1,393 kW.[14,15] Based on previously identified potential locations for SHP projects, SHP potential in the country is estimated to be at least 49.7 MW. Thus, just below 3 per cent of the potential has been developed so far.[16] Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, installed and potential capacity estimates increased due to access to more accurate data.

The seven SHP plants in operation were all constructed in the second half of the 20th century, the last of which was constructed in 1994 (Table 1). All of the plants are located in the south-eastern region, close to the border with Brazil. They were each constructed with the purpose to serve specific remote or indigenous communities with populations of 1,200 people or less.[14]

Figure 2. **Small Hydropower Capacities in the WSHPDR 2019/2022 in Venezuela (MW)**

Source: López-González,[14] CORPOELEC,[15] GEOA,[16] *WSHPDR 2019*[17]

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

Name	*River*	*Installed capacity (MW)*	*Year*
Canaima	Carrao	0.800	1994
Ciudadela	Aponguao	0.120	1994
Cúao	Cúao	0.030	1990
Arautamerú	Yuruaní	0.150	1988
Wonken	Caruay y Macarupuey	0.058	1983
Kamarata	Tapere	0.125	1962
Kavanayen	Apacairao	0.110	1957
Total		**1.393**	

Source: López-González,[14] CORPOELEC[15]

Though no SHP plants have been constructed in recent years, several potential sites have been identified as possible future projects with a total potential capacity of 48.29 MW (Table 2).

Table 2. **List of Potential Small Hydropower Projects in Venezuela**

Region	*River*	*Potential capacity (MW)*
Perija	El Palmar	3.20
Perija	Apon	3.10
Nor Occidental Andina	La Grita	8.20
Nor Occidental Andina	Motatan	3.52
Nor Occidental Andina	Torondoy	3.40
Sur Occidental Andina	Acequia	8.39
Sur Occidental Andina	Guache	4.30
Sur Occidental Andina	Masparro	2.29
Amazonas	Cataniapo	10.00
Amazonas	Villacoa	1.89
Total		**48.29**

Source: GOEA[16]

There are no known feed-in tariffs or other incentives for SHP. As the country is in a protracted electricity-sector crisis, SHP could be one of the solutions to ensure more efficient access to electricity.

RENEWABLE ENERGY POLICY

The dissemination of diverse renewable energy sources in the country has been considered slow and thus Venezuela is mostly relying on fossil fuel production and large hydropower.

The Homeland Programme and the Economic and Social Development Plan of the Nation 2013–2019 explicitly express national interest in expanding renewable energy in the country. Particular emphasis was put on wind and solar energy in order to diversify the energy mix. The programme aimed to develop an additional 613 MW from renewable energy sources by 2019, approximately 500 MW of which was to be from wind power sources.[19] No further updates or reports of the plan have been made official since, but the goal was not reached in the desired time frame. In response to the lack of attention from the Government to initiating new renewable energy projects, the country's scientists and non-governmental organizations (NGOs) have been on the forefront of pushing for the transition.[20]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The barriers to SHP development might also apply to the dissemination of other renewable energy resources. 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.

Enablers to SHP development in Venezuela include:

- More SHP plants would lessen reliance on the major Simon Bolivar hydropower plant;
- As most hydropower plants are located in the eastern or southern regions, SHP development in the north-western region would lower transmission distance and could increase energy stability.

REFERENCES

1. World Bank (2020). *Population, total: Venezuela, RB.* Available at https://data.worldbank.org/indicator/SP.POP.TOTL?locations=VE (Accessed 7 March 2022).
2. World Data (2022). *Venezuela Country Data and Statistics.* Available at https://www.worlddata.info/america/venezuela/index.php (Accessed 7 March 2022).
3. Encyclopaedia Britannica (2022). *Venezuela.* Available at https://www.britannica.com/place/Venezuela (Accessed 7 March 2022).
4. Scientific American (2021). *Where Climate Change Fits into Venezuela's Ongoing Crisis.* Available at https://www.scientificamerican.com/article/where-climate-change-fits-into-venezuela-rsquo-s-ongoing-crisis/ (Accessed 7 March 2022).
5. Academy of Physical, Mathematical and Natural Sciences (ACFIMAN) (2018). *Primer Reporte Académico de Cambio Climático.* Available at http://54.39.107.28/~acfimano/obras/wp-content/uploads/2021/02/LIBRO_RESUMEN_PRACC.pdf [in Spanish] (Accessed 14 March 2022).
6. Climates to Travel (n.d.). *Climate – Venezuela.* Available at www.climatestotravel.com/climate/venezuela (Accessed 7 March 2022).
7. United States Library of Congress (n.d.). *Country Studies: Venezuela, Rivers.* Available at http://countrystudies.us/venezuela/10.htm (Accessed 7 March 2022).
8. Venezuelan Association of Engineering, Electrical, Mechanical and Related Professions (AVIEM) (2021). *Revista 6: AVIEM Presente en el País.* Available at http://aviem.org/wp-content/uploads/2020/07/Numero-06-AVIEM-3.pdf [in Spanish] (Accessed 14 March 2022).
9. Giraldo López, J. (2019). *Solo 38,2% de la Capacidad de Generación Eléctrica en Venezuela Está Funcionando.* Available at https://www.larepublica.co/globoeconomia/solo-382-de-la-capacidad-de-generacion-electrica-en-venezuela-esta-funcionando-2838297 [in Spanish] (Accessed 8 March 2022).
10. Datos Mundial (2019). *Gestión de Energía en Venezuela.* Available at https://www.datosmundial.com/america/venezuela/balance-energetico.php (Accessed 8 March 2022).
11. National Electricity Company (CORPOELEC) (n.d.). *Quinés Somos.* Available at http://www.corpoelec.gob.ve/qui%C3%A9nes-somos [in Spanish] (Accessed 9 March 2022).
12. Pardo, D. (2015). *Por Que Se Va Tanto la Luz en Venezuela.* BBC news. Available at https://www.bbc.com/mundo/noticias/2015/10/151028_venezuela_luz_electricidad_crisis_dp [in Spanish] (Accessed 9 March 2022).
13. El Impulso (2021). *Corpoelec Aumenta Tarifas Más de 3.000% al Diezmado sector Empresarial de Bolívar.* Available at https://www.elimpulso.com/2021/01/19/corpoelec-aumenta-tarifas-mas-de-3-000-al-diezmado-sector-empresarial-de-bolivar/ [in Spanish] (Accessed 9 March 2022).
14. López-González, A. (2021). *Energías Renovables en Venezuela: Experiencias y Lecciones para un Futuro Sostenible.* Available at https://docplayer.es/222999986-Energias-ren-

ovables-en-venezuela.html#show_full_text [in Spanish] (Accessed 10 March 2022).
15. National Electricity Company (CORPOELEC) (2014). *MPPEE, CORPOELEC y FUNDELEC Realizaron Visita a Modelos Hidráulicos en Macagua*. Available at http://www.corpoelec.gob.ve/noticias/mppee-corpoelec-y-fundelec-realizaron-visita-modelos-hidr%C3%A1ulicos-en-macagua [in Spanish] (Accessed 10 March 2022).
16. 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. Available at https://grupoorinoco.files.wordpress.com/2015/07/potencial-hidroelc3a9ctrico-nacional-j-gc3b3mez.pdf [in Spanish] (Accessed 10 March 2022).
17. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
18. Transparency Venezuela (n.d.). Ley Orgánica del Sector Eléctrico. Available at https://transparencia.org.ve/project/ley-organica-del-sector-electrico/#:~:text=Esta%20ley%20tiene%20por%20objeto,la%20poblaci%C3%B3n%20de%20bajos%20ingresos. [in Spanish] (Accessed 10 March 2022).
19. International Renewable Energy Agency (IRENA) (2015). *Renewable Policy Brief: Venezuela*. Available at https://www.irena.org (Accessed 10 March 2022).
20. The Borgen Project (2021). *Renewable Energy in Venezuela*. Available at: https://borgenproject.org/renewable-energy-in-venezuela/ (Accessed 10 March 2022).

Contributing organizations

University Politehnica of Bucharest UPB 1818

Punjab Power Development Board
Energy Department

REESSA CONSULTING
ENERGY STORAGE

Samfunnsbedriftene
Energi

SEDE
CONSULTING

SMEC
Member of the Surbana Jurong Group

ENGINEERING GENERAL CONSULTANTS
EGC (PVT.) LTD.

Universidad Tecnológica de Panamá 1981

Национальная Академия наук Республики Таджикистан
тадж. Академияи миллии илмҳои Ҷумҳурии Тоҷикистон

SGP The GEF Small Grants Programme
DOMINICAN REPUBLIC
gef
UN DP

USP
THE UNIVERSITY OF THE SOUTH PACIFIC

UCL
THE BARTLETT ENERGY INSTITUTE

Universidad Central "Marta Abreu" de Las Villas

UNIVERSIDAD DE MURCIA

Universidad de Oriente
Santiago de Cuba

UniKL
UNIVERSITI KUALA LUMPUR

UTM
UNIVERSITI TEKNOLOGI MALAYSIA

UNIVERSITY OF ARCHITECTURE CIVIL ENGINEERING AND GEODESY

UNIVERSITY OF LATVIA

UCG

Université des Sciences et de la Technologie d'Oran - Med Boudiaf
USTO MB

MCMXXII
VYTAUTAS MAGNUS UNIVERSITY

Wasser World

Ministry of Energy & Power Development
Zimbabwe

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Vienna International Centre
P.O. Box 300 · 1400 Vienna · Austria
Tel.: (+43-1) 26026-o
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