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World Small Hydropower Development Report 2022

Middle Africa

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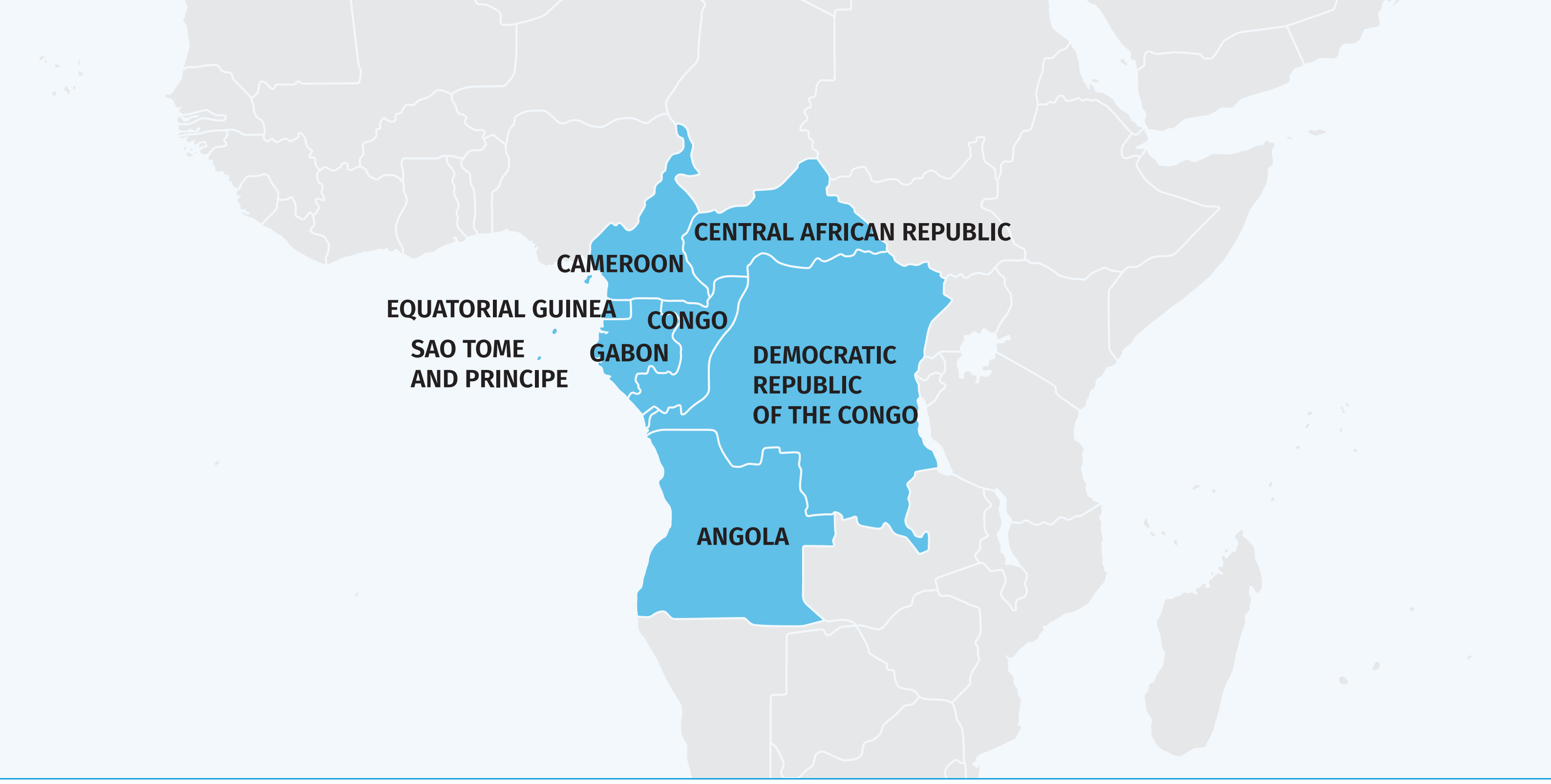


Middle Africa

Countries: Angola, Cameroon, Central African Republic, Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon, Sao Tome and Principe

INTRODUCTION TO THE REGION

Middle Africa is well-supplied with water resources and hydropower is the primary source of electricity generation for most countries in the region. The exceptions include Sao Tome and Principe and Congo, which rely heavily on thermal power, and Gabon, which is well-supplied with domestic fossil fuel resources and where thermal power forms the mainstay of electricity generation along with hydropower. In other countries in the region, thermal power plays a supplementary role, providing a very significant share of installed capacity but contributing only a small share of total electricity generation. Renewable energy resources other than hydropower are represented mainly by solar power and bioenergy, although their contribution to electricity generation is minor.

In many countries in the region, nationwide electricity access stands at less than 50 per cent, with very significant disparities between urban and rural areas across the entire region apart from Sao Tome and Principe. The lack of electricity access in such countries as Angola and the Democratic Republic of the Congo, both major electricity producers, highlights the insufficient connectivity and reliability of the transmission and distribution networks, with transmission and distribution losses in some countries reaching 40 per cent of total generation. In this context, distributed power generation could potentially have a positive impact on regional rates of electricity access.

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

Table 1. **Overview of Middle Africa**

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)
Angola	31	46	7	5,931	17,777	3,729	12,562
Cameroon	27	65	25	1,547	7,006	950	5,230
Central African Republic	5	32	16	41	157	19	148
Congo	6	48	13	794	2,988	228	872
Democratic Republic of the Congo	90	19	1	2,802	9,990	2,750	9,855
Equatorial Guinea	1	67	7	406	479	127	448
Gabon	2	93	63	632	2,332	332	981
Sao Tome and Principe	0.2	76	71	39	110	2	5
Total	-	-	-	**12,193**	-	**8,137**	-

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

In the Middle Africa region, the definition small hydropower (SHP) as hydropower plants with an installed capacity of up to 10 MW is adhered to by Angola, the Central African Republic, the Democratic Republic of the Congo, and Sao Tome and Principe. Additionally, in Angola the up to 50 MW definition is used on occasion. In Cameroon, SHP is defined as plants up to 5 MW in the context of rural electrification programmes. No official definition of SHP exists in Congo, Equatorial Guinea and Gabon.

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

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

Country	Local SHP definition	Installed capacity (local def.)	Potential capacity (local def.)	Installed capacity (≤10 MW)	Potential capacity (≤10 MW)
Angola	Up to 10 MW	46.1	600.0	46.1	600.0
Cameroon	Up to 5 MW	1.5	N/A	1.5	970.0
Central African Republic	Up to 10 MW	18.8	41.0	18.8	41.0
Congo	N/A	N/A	N/A	0.0	70.5
Democratic Republic of the Congo	Up to 10 MW	56.0	100.9	56.0	100.9
Equatorial Guinea	N/A	N/A	N/A	7.5	31.9
Gabon	N/A	N/A	N/A	6.0	518.1
Sao Tome and Principe	Up to 10 MW	1.9	63.8	1.9	63.8
Total	-	-	-	**137.8**	**2,396.2**

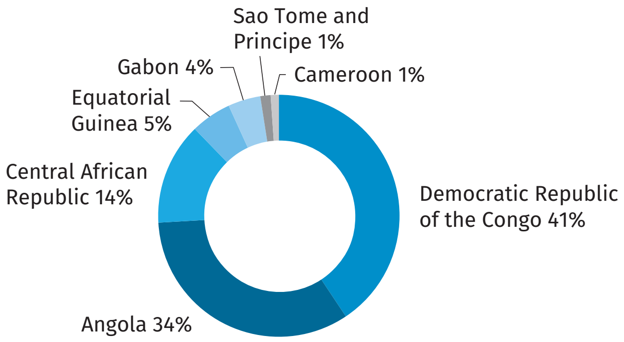
Source: *WSHPDR 2022*[1]

The total installed capacity of SHP up to 10 MW in Middle Africa is 137.8 MW, while the potential capacity is estimated at 2,396.2 MW. Relative to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity has increased by 21 per cent, largely due to more accurate data becoming available on the total capacity of SHP plants in Angola. Small increases in installed capacity were also observed in Cameroon and Gabon, while in the rest of the region installed SHP capacity either remained the same or actually declined. The estimate of potential capacity increased by 29 per cent, largely due to the availability of new data on the technical SHP potential in Gabon.

SHP plays a particularly important role in the Central African Republic and Sao Tome and Principe, where it accounts for 100 per cent of installed hydropower capacity. In other countries in the Middle Africa region, the hydropower sector is dominated by large-scale plants and the contribution of SHP to the generation of electricity is relatively small. Recent activities in the SHP sector in the region have mainly focused on the rehabilitation of existing SHP plants, although one new plant was commissioned in 2021 in Cameroon.

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.

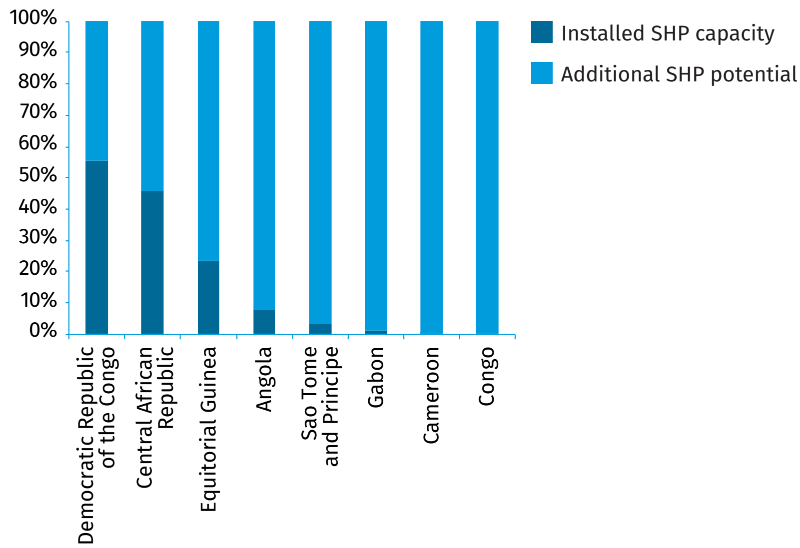
Figure 1. **Share of Regional Installed Capacity of Small Hydropower up to 10 MW by Country in Middle Africa (%)**



Source: *WSHPDR 2022*[1]

Note: Congo not included due to a lack of SHP capacity.

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



Source: *WSHPDR 2022*[1]

The installed capacity of SHP up to 10 MW in **Angola** is 46.1 MW, while the potential capacity is estimated at 600 MW, indicating that nearly 8 per cent has been developed. The identified potential is contained in 100 different sites identified in 2015 as part of the country's Energy Strategy to 2025. Of these, at least six have been selected for priority investment by 2025.

In **Cameroon**, the installed capacity of SHP up to 10 MW is 1.5 MW, accounted for by a single SHP plant. The country's SHP potential is estimated at 970 MW, indicating that less than 1 per cent has been developed, but no detailed assessment of existing sites is available. One SHP project with an installed capacity of 2.9 MW is under development, but its commissioning was stopped due to the civil war.

The **Central African Republic** has an installed capacity of 18.8 MW for SHP of up to 10 MW, while estimated potential capacity is 41 MW, indicating that 46 per cent has been developed. The country has two SHP plants in operation, while construction of a third plant with a capacity of 10 MW was suspended due to political instability, and the plant is in need of rehabilitation.

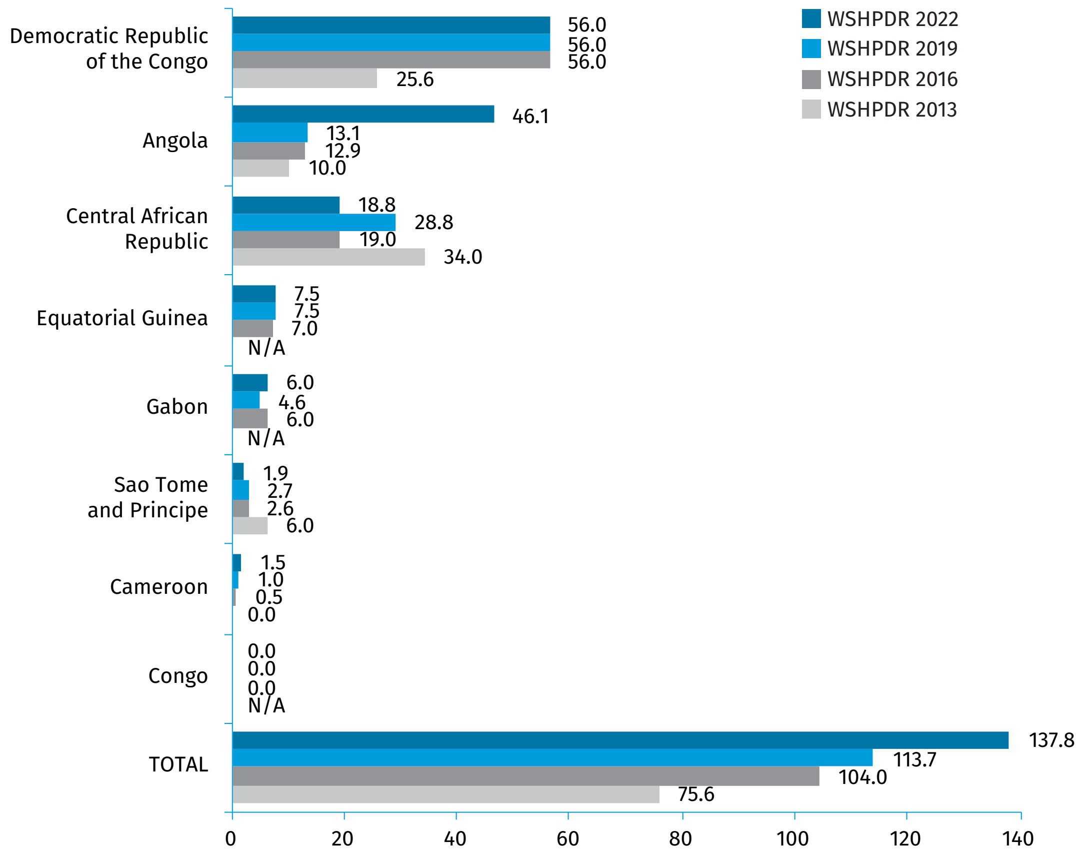
At least 15 sites suitable for SHP development have been identified in the country, and the construction of one additional SHP project is ongoing as of 2021.

There is no installed SHP capacity in **Congo**. The potential capacity for SHP has been most recently estimated at 75 MW and is entirely undeveloped. At least 27 potential SHP sites have been identified throughout the country, with capacities ranging between 6 kW and 10 MW. Several feasibility studies of potential SHP sites supported by various international institutions have been recently completed, and a number of additional studies were either ongoing or in the planning stages as of 2021.

In **the Democratic Republic of the Congo**, the installed capacity for SHP of up to 10 MW is 56 MW, while potential capacity is estimated at 100.9 MW, indicating that 55 per cent has been developed. No new SHP construction has taken place in the country in the last several years, although five new SHP projects were in the planning stages as of 2021.

The installed capacity for SHP of up to 10 MW in **Equatorial Guinea** is 7.5 MW, while potential capacity is estimated at 31.9 MW, indicating that nearly 24 per cent has been developed. There are three operational SHP plants in the country, with the largest one, the 3.8 MW Riaba SHP plant, operating at only a fraction of its installed capacity and in need of extensive repairs and upgrades. At least 36 potential SHP sites have been identified in the country and detailed evaluations of the sites are ongoing.

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



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

Gabon has an installed capacity of 6 MW for SHP of up to 10 MW, provided by three SHP plants. The potential capacity is estimated at 518.1 MW, indicating that approximately 1 per cent has been developed. Recent activity in the SHP sector in the country has been limited to the refurbishment of existing plants and updated studies of the country's SHP potential.

In **Sao Tome and Principe**, the installed capacity for SHP up to 10 MW is 1.9 MW while potential is estimated at 63.8 MW, indicating that approximately 3 per cent has been developed. There is only one operational SHP plant in the country, while three others have been decommissioned and are in need of extensive refurbishment or reconstruction. Thirty-four potential SHP sites have been identified in the country, but no new SHP projects are currently planned.

Changes in the installed capacities of SHP up to 10 MW in the countries in the region compared to the previous editions of the *WSHPDR* are displayed in Figure 3.

Climate Change and Small Hydropower

Countries in the Zambezi River basin, which includes Angola, have already experienced climate change, especially rainfall variability. The projected continuous rise in evaporation and evapotranspiration due to increased temperatures could spur higher water stress in the region. However, the impacts on runoff are yet uncertain.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The main barriers to SHP development in **Angola** are the lack of stability in regulations governing asset ownership, the awarding and return of concessions, land acquisition and power purchase agreements, as well as a general lack of experience with investor relations, public-partner partnerships and Build-Operate-Transfer schemes. Additionally, the country has limited technical expertise in the SHP sector, with large hydropower taking precedence in national development.
At the same time, the large untapped SHP potential in the country and favourable topography, a multitude of identified SHP sites offer many opportunities for investment in the sector, particularly in light of increasing access to international financing.

Obstacles to SHP development in **Cameroon** include a lack of detailed assessments of SHP potential, lack of financing, unreliable infrastructure and an absence of local capacity for manufacturing electromechanical equipment. Enablers include the very significant untapped SHP potential in the country, increasing momentum in favour of renewable energy resource development and the strong need for rural electrification.

SHP development in the **Central African Republic** is hampered by a lack of incentives, monopolization of the electricity sector, which discourages investors, lack of technical capacity, limited financial resources and political unrest. However, the topography and hydrology of the country are overall favourable for SHP and projects can be undertaken with the support of a number of international institutions and financing mechanisms that have a presence in the country.

In **Congo**, barriers to SHP development include a lack of incentives and technical capacity, high cost of electricity transmission, gaps in the legal and regulatory framework regarding SHP, and expected decreases in river flow during the dry season, which could undermine the viability of run-of-river plants. The main enablers for SHP development in the country are the untapped SHP potential and a relatively liberalized electricity market.

The development of SHP in **the Democratic Republic of the Congo** is held back by the weak enforcement of the institutional and regulatory framework for private investment in the energy sector, high cost of development, lack of affordable financial mechanisms, lack of a renewable energy policy and focus on large-scale generation. The liberalization law passed in 2014 could act as an incentive for SHP development if properly enforced, allowing the country to take advantage of its substantial untapped SHP potential.

The main barrier to SHP development in **Equatorial Guinea** is the high cost of SHP relative to other energy sources, in particular subsidized fossil fuels, as well as lack of incentives for renewable energy and lack of detailed data on potential sites. The main enablers are the remaining untapped SHP potential and interest in SHP development in the country on the part of international development institutions.

Barriers to SHP development in **Gabon** include inadequate infrastructure, lack of local expertise, high costs and excessive bureaucratization. However, the regulatory environment for private investment is expected to improve and the country is aiming to transition from an oil-based economy to one reliant on renewable energy. The SHP sector is expected to benefit from the system-scale approach outlined in the Government's planned changes to the licensing process for hydropower projects, and be able to take advantage of the recently-identified and large SHP potential.

The main barrier to SHP development in **Sao Tome and Principe** is the lack of an institutional framework and policy mechanisms that would enable the realization of the country's identified SHP potential. However, SHP is seen as a promising solution for extending electricity access to the country's rural and remote areas, as well as decreasing its heavy reliance on fossil fuels.

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/WSHPDR.
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.

Angola

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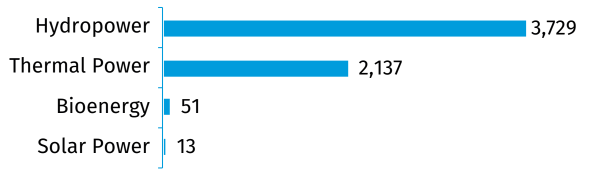
KEY FACTS

Population	31,127,674 (est. 2020)[1]
Area	1,246,700 km^2 [2]
Topography	The topography of Angola is characterized by a narrow coastal plain in the west from which rise broad tablelands lying at over 1,000 metres above sea level, a high plateau in the centre and mountain ranges to the south reaching up to 2,400 metres. The highest point is Mount Moco, at 2,620 metres above sea level, in the Huambo Province.[3,4]
Climate	The climate in Angola is tropical, with a warm rainy season from September to May and a cooler dry season from June to August. The country is divided into two climatic regions, the coast and interior. The annual average temperature ranges between a minimum of 17 °C and a maximum of 27 °C.[2]
Climate Change	Based on historical data, the mean temperature increased by 1.5 °C from 1960 to 2016. The frequency of hot days increased, while cold days decreased in the period of 1960–2003. The mean annual precipitation has been decreasing, at an average rate of 2 mm per decade. A greater decrease in late summer precipitation and increase in precipitation variability in the central-south transition area have also been observed. Climate models have predicted a continuous increase in temperature. From 2040 to 2059, an increase of 2 °C is projected, with rapid warming to take place in the interior and eastern parts of the country. There is a wide range of predictions for the change in precipitation across the country, with the predominant prediction indicating a decrease of mean annual precipitation by almost 14 mm (CMIP5 projections, RCP 8.5, Ensemble). However, the annual maximum 5-day rainfall for a 25-year period return is expected to rise by 15 mm.[5,6]
Rain Pattern	The cooler months in Angola (June–August) are very dry, with almost no rainfall. The wet season (October–April) receives between 100 mm and 250 mm of rainfall per month. The total rainfall decreases from north-east towards south and the western coast. Annual rainfall averages 984 mm.[2,4,5]
Hydrology	Most of the rivers in Angola rise in the central mountains, draining in all directions. The perennial rivers are concentrated in the north and centre, while in the south there are only three perennial rivers: the Cunene, Cuando and Cubango. Of the many rivers draining into the Atlantic Ocean, the most important ones are the Cuanza and Cunene. Other major rivers include the Cuango, draining northwards to the Congo River system, as well as the Cuando and Cubango Rivers, draining south-eastwards to the Okavango Delta in Botswana. There are no sizable natural lakes in Angola.[4,7]

ELECTRICITY SECTOR OVERVIEW

Electricity generation in Angola in 2019 was 17,777 GWh. Approximately 71 per cent of this total was from hydropower, almost 28 per cent was produced by oil- and gas-fired thermal power plants and approximately 1 per cent was from bioenergy and solar power (Figure 1).[8]

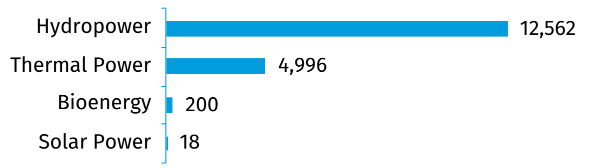
Figure 1. **Annual Electricity Generation by Source in Angola in 2019 (GWh)**



Source: IRENA[8]

In 2020, the total installed capacity of Angola reached 5,931 MW, of which 63 per cent was from hydropower, 36 per cent from thermal power and another 1 per cent from bioenergy and solar power plants (Figure 2).[8] The increase in capacity in recent years mainly originated from the hydropower plants of Cambambe 2 and Laúca, with 960 MW and 1,670 MW (five units out of six already commissioned), respectively, and the thermal combined-cycle power plant of Soyo, with 500 MW.[9]

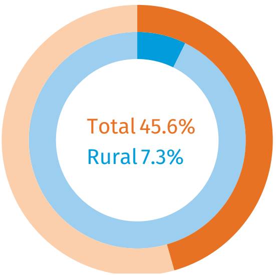
Figure 2. **Installed Electricity Capacity by Source in Angola in 2020 (MW)**



Source: IRENA[8]

In 2019, 45.6 per cent of the population of Angola had access to electricity, with almost 74 per cent access in urban areas, while the most recent data from the World Bank indicate that only 7.3 per cent of rural areas had access to electricity in 2018 (Figure 3).[10] The rate of electrification is not homogeneous throughout the country.[11] The National Company for the Distribution of Electricity (ENDE) had a total of 1,585,000 clients in 2018 divided into residential, services and industrial consumers. For comparison, in 2015 ENDE served 1,275,468 clients. Of the customers served by ENDE, approximately 200,000 were provided with electricity through prepaid meters.[9,12]

Figure 3. **Electrification Rate in Angola in 2018 (%)**



Source: World Bank[10]

The electricity consumption in Angola reached 11.6 TWh, in 2020.[13] According to United Nations Statistics Division (UNSD) data, between 2014 and 2018 electricity consumption increased by 24 per cent. In 2018, households accounted for 59 per cent of total consumption and losses amounted to 12 per cent.[14] With uneven electrification, the consumption is concentrated in the northern region.[4]

The Regulatory Institute for Electricity and Water (IRSEA) was established in 2016 by Decree No. 59/16, transferring all rights and obligations from the Regulatory Institute for Electricity Sector (IRSE). The role of IRSEA is to regulate activities of production, transport, distribution, sale and use of electricity in the Public Electricity System (SEP) as well as to regulate the commercial relationship between SEP and agents that are not linked to it.[15] The design principles of this established model aim to develop a competitive process for both public and private generation and to establish an Independent Transmission Operator, which will also act as a single buyer for all electricity generated in the SEP.[4]

The electricity tariff categories are approved by Presidential Decrees No. 4/11 and No. 178/20 and defined by Executive Decree No. 122/19, which provides the basis for the calculation of tariffs. The rates are composed of two components, one based on the power and the other one based on consumption. The low voltage tariff rates are within the range of 2.46–14.74 AOA/kWh (0.004–0.026 USD/kWh), medium voltage rates are 9.61–11.54 AOA/kWh (0.017–0.020 USD/kWh) and the high voltage rate is 7.31 AOA/kWh (0.013 USD/kWh) (Table 1).[15]

Table 1. **Electricity Tariffs in Angola**

Category	*Power component (AOA (USD) per unit)*	*Consumption component (AOA (USD) per kWh)*
Low voltage		
Social household I	0	2.46 (0.004)
Social household II	80.00 (0.140)	6.41 (0.011)
Street lighting	45.00 (0.080) x pc	7.05 (0.012)
Single-phase household	90.00 (0.160) x pc	10.89 (0.019)
Three-phase household	100.00 (0.180) x pc	14.74 (0.026)
Commerce and services	100.00 (0.180) x pc	14.74 (0.026)
Industry	100.00 (0.180) x pc	12.82 (0.023)
Medium voltage		
Commerce and services	160.00 (0.280) x P	11.54 (0.020)
Industry	160.00 (0.280) x P	9.61 (0.017)
High voltage		
Industry	115.00 (0.200) x P	7.31 (0.013)
Distributors	115.00 (0.200) x P	7.31 (0.013)

Source: IRSEA[15]

Note: pc — contracted power (kVA), P — the maximum point of 15 consecutive minutes (kW).

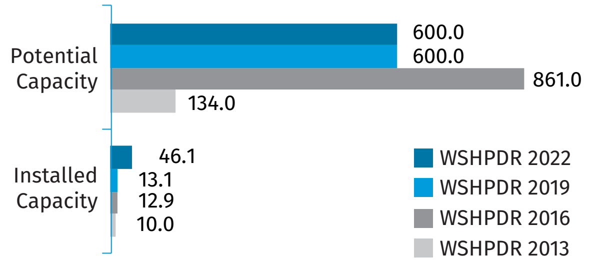
Presidential Decree No. 256/11, defining the National Policy and Strategy for Energy Security, established goals for the electricity sector until 2025.[16] For its implementation, short-term plans were defined. The plan for 2013–2017 fell short of what was initially planned. The following, 2018–2022 action plan has three development programmes and subprogrammes, which include the expansion of electricity access in urban areas, municipalities and rural areas; the optimization and sustainable management of the electricity sector; and private participation in the production and distribution of electricity.[4,11]

SMALL HYDROPOWER SECTOR OVERVIEW

The common definition of small hydropower (SHP) in Angola is up to 10 MW, although plants of up to 50 MW are often referred to as SHP as opposed to large hydropower of up to 1,000 MW and 2,000 MW. The installed capacity of SHP in Angola amounts to 46.1 MW (Table 2), indicating a significant increase since the *World Small Hydropower Development Report (WSHPDR) 2019* (Figure 4). The estimated potential capacity, as identified by the Angola Energy Strategy 2025 of the Ministry of Energy and Water (MINEA), is 600 MW from 100 different sites.[18] A list of known planned SHP projects is presented in Table 3.

Figure 4 presents a summary of SHP data made available by the National Water Resources Information System (INRH) and the Public Electricity Production Company (PRODEL-EP).[19,20] However, this list has not been updated since the publication of the *WSHPDR 2019*, providing the same estimate of SHP installed capacity of 13.1 MW as reported in the previous edition. Additionally, it is also known that ENDE manages SHP plants of up to 5 MW each, with a total installed capacity of 33 MW.[11] The sum of these two figures gives the installed capacity of 46.1 MW. The significant increase in SHP installed capacity since the previous edition of the report may be related to the uneven dispersion of information, in addition to the new investments made in this sector.

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



Source: *WSHPDR 2019*,[4] Gesto,[11] National Energy Atlas,[18] INRH,[19] PRODEL-EP,[20] *WSHPDR 2013*,[21] *WSHPDR 2016*[22]

Note: Data for SHP up to 10 MW.

Angola has a significant hydropower potential. However, the development and rehabilitation of power plants have not succeeded in keeping the supply in line with the expanding demand. The technical potential is estimated at approximately 80 TWh/year and the economic potential is 72 TWh/year (18 GW). Information on SHP potential in the country was assembled in the Atlas of the Hydropower Resource.[15,18,23]

Table 2. **List of Selected Operational Small Hydropower Plants in Angola (up to 50 MW)**

Name	*Location*	*Capacity (MW)*
Lomaum	Benguela	50.0
Matala	Huíla	40.8
Mabubas	Uíge	25.6
Chicapa	Lunda Sul Province	16.0
Biópio	Benguela	15.2
Chiumbe Dala	Lunda Sul Province	12.0
Cunje II	Bié	7.5
Luquixe II	Uíge	2.1
Cunje I	Bié	1.6
Rápidos do rio lifune	Nambuangongo, Muxaluando	1.1
Cuando	Huambo	1.0

Source: INRH,[19] PRODEL-EP[20]

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

Name	*Location*	*Capacity (MW)*	*Stage of development*
Luachimo	Lunda Norte	8.4	Works ongoing
Luquixi	Uíge	2.1	Rehabilitation

Source: INRH,[19] PRODEL-EP[20]

The national plan for the electricity sector up to 2025 intends to develop new SHP plants for achieving the renewable energy installed capacity targets and to promote electrification of isolated rural areas.[15] From the 100 potential locations identified for SHP by MINEA, seven were selected with potential to supply nine municipal townships through isolated systems, including the Cutato, Quedas de Kaquina and M'Pupa Rapids SHP plants.[15,24,27] The 2025 Angola Power Sector Long-Term Vision lists the priority investments for the 2018–2025 horizon, with several potential SHP projects identified for priority investment (Table 4). Other potential sites not identified in the long-term vision also remain available for SHP development (Table 5).

Table 4. **Small Hydropower Sites Prioritized for Investment for the 2018–2025 Horizon**

Name	*Capacity (MW)*	*Total Investment (USD million)*
Andulo	0.5	3.1
Kuito 2	0.6	3.7
Kuando	2.0	12.4
Liapeca	4.0	24.8
M'Bridge	4.6	28.4
Other ongrid	48.0	240.7
Cuemba (off-grid)	0.5	3.1
Other off-grid	28.3	220.5

Source: MINEA[17]

Table 5. **List of Small Hydropower Projects Available for Investment**

Name	*Location*	*Potential capacity (MW)*	*Type of site (new/refurbishment)*
F.Caála	Balombo	1.22	New
Balombo	Balombo	9.60	New
Freitas morna	Ambriz, Bela vista	8.00	New
Rápidos do rio lifune	Nambuangongo, Muxaluando	1.06	New
Bocoio	Bocoio	2.58	New

Source: National Energy Atlas[18]

RENEWABLE ENERGY POLICY

The Electricity Sector Transformation Programme (PTSE) is a result of the National Policy and Strategy for Energy Security and is divided into four implementation phases, the latest being over the period 2021–2025. It proposed a power sector reform involving three different measures: diagnosis, mobilization and change management; electric sector restructuring; and operational and functional improvement of public companies, implemented from 2012 to 2016. The studies conducted by this programme also recommend the incentivized participation of the private sector in renewable energy development in rural areas via feed-in tariffs and a partial liberalization of distribution systems and the energy sector, including full participation of independent power producers (IPPs) and the improvement of the energy mix.[4,25,28] This is proposed to be implemented until 2025.[28] Recently, in 2021, a law was established for independent energy production.

The restructuring of the electricity sector began in 1996, with the publication of the General Electricity Law 14-A/96, which, together with the Energy Security Policy of 2011, paved the way for the publication of new regulations essential for the energy market, and the amendment of the General Electricity Law, Law No. 27/15. Laws and Regulations published to establish the legal regime for the exercise of the activities of generation, distribution and supply of electricity, including by IPPs, are:

- General Electricity Law No. 14-A/96;
- General Electricity Law No. 27/15;
- Electricity Production, Transport, Distribution and Commercialization Activities Regulation, Presidential Decree No. 76/21;
- Electricity Supply Regulation, Presidential Decree No. 27/01;
- Regulation of Independent Electric Energy Production, approved by Presidential Decree No. 43/21;
- Regulation on the licensing of facilities for the use of electricity, Presidential Decree No. 40/04;
- Regulation of Electricity Production, Transport and Distribution facilities, Presidential Decree No. 41/04;
- Private investment law, Presidential Decree No. 10/21.[15,26]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

In early 2021, some changes were made in the regulatory framework of Angola which encourage the renewable energy sector, namely Decrees No. 76/21 and 43/21.[15] Furthermore, the Government of Angola has a specific decree for the model of concession contracts and the purchase and sale of electricity for SHP projects (No. 82/10). This is a legal instrument for public-private partnerships, aiming at the launch of the public tender for SHP and associated transport systems, as part of MINEA's intention to promote access to electricity in the isolated locations of the country.

The high-potential SHP sites identified under the Angola Energy Strategy 2025 programme are to be further studied. These feasibility studies aim to launch tenders for a total of 100 MW in mini- and small-scale hydropower projects.[17]

COST OF SMALL HYDROPOWER DEVELOPMENT

The mean cost of SHP installed in Angola is estimated at approximately 6.2 million USD/MW (Table 6), with the values being based on the Angola Energy 2025 strategy.[18]

Table 6. **Estimation of Small Hydropower Development Costs in Angola**

Name	*Cost (million USD/MW)*
Andulo	6.20
Kuito 2	6.17
Kuando	6.20
Liapeca	6.20
M'Bridge	6.17
Cuemba	6.20

Source: MINEA[18]

FINANCIAL MECHANISMS FOR SMALL HYROPOWER PROJECTS

The Angola action plan for the energy sector 2018–2022 mentions that the main sources of financing of energy sector projects are: the Public Investment Programme (ordinary revenue of the treasury or the external and internal funding); revenues and financing of companies in the sector; or private investment with contingency guarantees.[11] Some policies are planned to be defined in Angola, including financial incentives, such as:

- Agreement for power purchase (PPAs) with feed-in tariffs over a reasonable period of time;
- Setting rates of return-on-investment for capital;
- Tax reductions (e.g., on income tax and imports).

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

The climate projections predict a continuous temperature increase of approximately 2 °C from 2040 to 2059. This increase will lead to a rise of evaporation and evapotranspiration. The loss of water by evaporation in a reservoir can reduce the attractiveness of storage SHP plants. Besides, climate change will globally decrease mean annual precipitation by approximately 13 mm in the same timeframe. The impact that increased temperature and evapotranspiration may have on runoff is yet uncertain and must be closely monitored since it may reduce the availability of water for SHP operation.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

There are still several barriers to SHP dissemination in Angola, including:

- Limited experience of developing energy projects with private investors, as IPPs under Build–Operate–Transfer (BOT) or similar arrangements, as well as in the form of public-private partnerships;
- Lack of stability in the rule of law and governance, for asset ownership, concession award and return, land acquisition, claim management, power purchase/selling and unpaid bills retrieval;
- Deficient long-term financial models for providing affordable renewable energy to customers;
- Limited availability of technologies for mini, micro- and pico-hydropower;
- Fragile operation and management framework, regarding norms and standards and human resources capacity;
- Power purchase agreements priced in the local currency.[4,29]

Nonetheless, there are also several enablers to SHP development in the country:

- Political will to facilitate investment in the energy sector;
- Favourable topography and water availability for SHP development;
- Increased presence of international financial institutions following the peaceful transition in presidential power in 2017.
-

REFERENCES

1. Instituto Nacional de Estatísticas (n.d.). *População*. Available at https://www.ine.gov.ao/inicio/estatisticas (Accessed 31 March 2021).
2. Angola Government portal (n.d.). *Sobre Angola.* Available at https://governo.gov.ao/ao/angola/sobre-angola/ (Accessed 31 March 2021).
3. Diniz, A.C. (1973). *Características Mesológicas de Angola. 2ª Edição. Missão de Inquéritos de Angola*. Nova Lisboa. Angola. 482 p.
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.
5. World Bank (2021). *Angola – Climate Data – Historical*. Climate Change Knowledge Portal For Development Practitioners and Policy Makers. Available at https://climateknowledgeportal.worldbank.org/country/angola/climate-data-historical# (Accessed 31 March 2021).
6. World Bank (2021). *Angola – Climate Data – Projections*. Climate Change Knowledge Portal For Development Practitioners and Policy Makers. Available at https://climateknowledgeportal.worldbank.org/country/angola/climate-data-projections# (Accessed 31 March 2021).
7. Earthwise contributors (2020). *Hydrogeology of Angola*. Earthwise. Available at http://earthwise.bgs.ac.uk/index.php?title=Hydrogeology_of_Angola&oldid=45211 (Accessed 31 March 2021).
8. IRENA (2021). *Energy Profile Angola*. 29th September, 2021 Available at https://www.irena.org/Statistics/Statistical-Profiles (Accessed 22 November 2021).
9. Silva, L. M. (2019). *Welcome speech at the 12th Annual RELOP Conference*. Available at http://www.irsea.gov.ao/discurso-do-eng-o-luis-mourao-da-silva-durante-a-xii-conferencia-anual-da-relop/ (Accessed 31 March 2021).
10. World Bank (2021). *Access to electricity (% of population): Angola*. The World Bank. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=AO (Accessed 24 November 2021).
11. Gesto Energy Consulting (2018). *Angola: Action Plan of The Energy and Water Sector 2018-2022*. First Edition, Gesto-Energia, S.A. Available at https://gestoenergy.com/wp-content/uploads/2019/04/Angola-action-plan-of-the-energy-water-sector-2018-2022.pdf (Accessed 31 March 2021).
12. National Electricity Distribution Company (ENDE) (n.d.). *Sobre a ENDE*. Available at https://ende.co.ao/sobre/quem-somos/ (Accessed 31 March 2021).
13. Ministry of Energy and Water (MINEA) (2020). *Relatório de Balanço das Actividades MINEA 2020*. Luanda Angola Available at https://www.minea.gv.ao/index.php/planos--de-accao-do-minea/category/230-realact (Accessed 22 Novembro 2021).
14. United Nations Data (2021). *Statistics - Total Electricity*. United Nations Statistics Division. Available at http://data.un.org (Accessed 31 March 2021).
15. Electricity and Water Services Regulator [Regulador dos Serviços de Electricidade e do Abastecimento de Águas] (IRSEA) (n.d). *Electricity.* Available at http://www.irsea.gov.ao/electricidade (Accessed 31 March 2021).
16. Government of Angola (2011). *Presidential Decree No. 256/11*. Available at http://extwprlegs1.fao.org/docs/pdf/ang118351.pdf (Accessed 21 June 2021).
17. Ministry of Energy and Water (MINEA) (2016). *Angola Energia 2025: Angola Power Sector Long Term Vision*. First Edition, https://gestoenergy.com/wp-content/uploads/2018/04/ANGOLA-POWER-SECTOR-LONG-TERM-VISION.pdf (Accessed 31 March 2021).
18. Ministry of Energy and Water (MINEA) (2015). *Atlas and National Strategy for the Renewable Energies*. Available at https://angolaenergia2025.gestoenergy.com/sites/default/files/editor/atlas_e_estrategia_nacional_para_as_novas_energias_renovaveis.pdf (Accessed 21 June 2021).
19. National Institute of Water Resources [Instituto Nacional de Recursos Hidricos] (INRH) (n.d.). *Sistema Nacional de Informação de Recursos Hidricos de Angola*. INRH. Available at http://www.inrh.gv.ao/portal/snirha (Accessed 31 March 2021).
20. Public Company for Electricity Production, EP [Empresa Pública de Produção de Electricidade, EP] (PRODEL-EP) (n.d.). *Hydropower Production [Produção Hídrica]*. Available at http://www.prodel.co.ao/index.php/pt/producao-hidrica/

produca-hidrica-sub#undefined (Accessed 31 March 2021).
21. 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.
22. 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.
23. Ministry of Energy and Water (MINEA) (2014*). National Strategy for Renewable Energies. Final Version*. Available at https://www.minea.gv.ao/index.php/projectos-3/category/25-dner-direccao-nacional-de-energias-renovaveis#_ (Accessed 31 March 2021).
24. National Directorate of Rural and Local Electrification [Direcção Nacional de Electrificação Rural E local] (n.d.). *Desenvolvimento de Mini-Redes em Angola*. Presentation on the Webinar Evaluation of the Opportunities of the Mini-Network Market in Angola. Available at https://www.aler-renovaveis.org/pt/comunicacao/noticias/webinar-avaliacao-das-oportunidades-do-mercado-de-mini-redes-em-angola (Accessed 31 March 2021).
25. Saraiva, J. (2014). *Electric Sector Transformation Program (PTSE)*. Presentation of 18th A.P.U.A Congress. September 2014.
26. Silva, L. M. (2019). *Regulamentação do Sector das Energias em Angola.* Presentation for the International Forum on Renewable Energy. Available at http://www.ucm.minfin.gov.ao/cs/groups/public/documents/document/zmlu/mjiy/~edisp/minfin222662.pdf (Accessed 31 March 2021).
27. Ministry of Energy and Water (MINEA) (2016). *Perspectivas do Sectro Eléctrico para o Período de 2016/2017*. Presentation for the 6º Conselho Consultivo Energia e Água. 8th and 9th August 2016. Sumbe, Angola. Available at https://www.minea.gv.ao/index.php/projectos/category/47-energia?download=332:perspectivas-do-sector-electrico-para-o-periodo-2016-2017 (Accessed 21 November 2021).
28. Japan International Cooperation Agency (JICA), Tokyo Electric Power Services Co. (TEPSCO) & International Institute of Electric Power (IIEP) (2018). *The Project for Power Development Master Plan in the Republic of Angola, Final Report*. Available at https://openjicareport.jica.go.jp/pdf/12324307_01.pdf (Accessed 21 November 2021).
29. United States Agency for International Development (USAID) (2018). *Angola Fact Sheet.* Available at https://www.usaid.gov/sites/default/files/documents/1860/Angola_-_November_2018_Country_Fact_Sheet.pdf (Accessed 21 November 2021).

Cameroon

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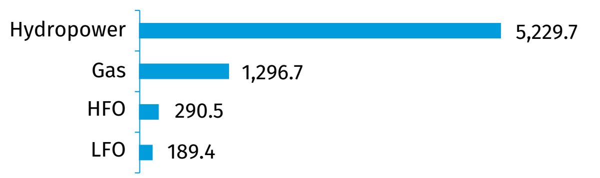
KEY FACTS

Population	27,224,262 (2021)[1]
Area	475,440 km[2]
Topography	Four geographical regions can be distinguished in Cameroon. The northern region is occupied by a savannah plain sloping down towards the Chad Basin. The central region is a transitional area between the western and northern regions and is dominated by the Adamawa Plateau at 900–1,500 metres above sea level. The north-western region consists of volcanic mountains reaching over 2,400 metres, with Mount Cameroon (4,095 metres) being the highest point in the country. Finally, the west is occupied by lowlands reaching up to 600 metres above sea level.[2]
Climate	The climate differs between the north and the south of the country. In the south there are two dry seasons, in November–March and in June–August, with mean temperatures ranging between 22 °C and 29 °C along the coast. In the north, the dry season lasts from October to March and temperatures range from 23 °C to 26 °C.[3]
Climate Change	Climate change has significantly affected Cameroon and disrupted weather and precipitation patterns, making trend predicting more complex. The observed effects include more frequent extreme weather conditions, false starts to seasons, heavier rainfall and as a result floods as well as recurrent droughts, which, in turn, have resulted in the advancement of the desert. These impacts are expected to become more severe as global warming continues. By 2100, the average annual temperature is predicted to see a 1.5–4.5 °C increase depending on the region.[4]
Rain Pattern	The average precipitation varies from 500 mm to approximately 3,000 mm, peaking at 10,000 mm at Mount Cameroon.[5]
Hydrology	In the south of Cameroon, water flows towards the Atlantic Ocean or the Congo River catchment via the Sangha River and in the north, towards the Benoue River or Lake Chad. Thus, the river system can be broken down into four subsystems of different sizes. The Atlantic catchment is the largest of the four subsystems, with the Sanaga River alone draining a catchment area of 135,000 km² and having a plurennial flow reaching 2,000 m³/s at Edea. The Sangha catchment includes three tributaries of the Sangha River, i.e., the Dja, Boumba and Kadei. The Sangha in its turn is a tributary of the Congo River. The Benoue River, forming the Benoue catchment area, is the largest of the Niger River's tributaries with a plurennial flow of 250 m³/s. The tributaries of Lake Chad include the Vina and Mbere. Both rivers form the western branch of the Logone, which runs into the Chari that feeds Lake Chad.[6]

ELECTRICITY SECTOR OVERVIEW

Total electricity generation in Cameroon in 2019 was approximately 7,006 GWh, of which hydropower accounted for almost 75 per cent, gas for almost 19 per cent, heavy fuel oil (HFO) for 4 per cent and light fuel oil (LFO) for almost 3 per cent (Figure 1).[7]

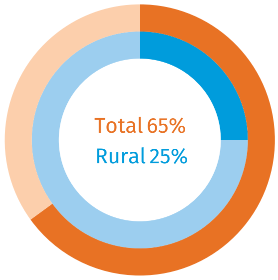
Figure 1. **Annual Electricity Generation by Source in Cameroon in 2019 (GWh)**



Source: Eneo[7]

The country's installed capacity is 1,547.3 MW, with hydropower accounting for 950 MW.[8] Hydropower is the main source of electricity generation. There are also several thermal power plants sustaining generation in grid-connected areas as well as operating off-grid. There are no electricity imports or exports, however, there are plans to connect Cameroon with Chad and Nigeria to mitigate the high cost of electricity generation in these countries. In 2020, the national electrification rate in Cameroon was nearly 65 per cent and the rural electricity access rate was 25 per cent (Figure 2).[9,10]

Figure 2. **Electrification Rate in Cameroon in 2020 (%)**



Source: World Bank[9,10]

The Ministry of Water and Energy (MINEE) and the Electricity Development Corporation (EDC) oversee the energy sector in Cameroon. The Rural Electrification Agency (AER) promotes rural electrification and the Electricity Sector Regulation Agency (ARSEL) approves electricity tariffs and determines electricity standards. The utility company Eneo is in charge of electricity generation and distribution, while the National Electricity Transport Company (SONATREL) manages the electricity transmission network. Cameroon has three main independent grids: the southern, eastern and northern grids. The electricity sector has been privatized since 1998. Kribi Development Corporation (KPDC), Dibanba Development Corporation (DPDC) and Memve'Ele are the most important generation companies outside Eneo. Nachtigal Hydro Company (NHPC) is constructing a 420 MW hydropower plant and will be the biggest generation company after Eneo.

After commissioning the first small hydropower (SHP) plants in the early 1930s, Cameroon switched to large-scale hydropower development, with a number of plants commissioned in the late 1980s. For several decades, no new hydropower plants were commissioned in Cameroon due to an unfavourable economic situation. Nonetheless, hydropower remains the main source of electricity generation in the country. However, there are also plans to develop large-scale solar power plants to reduce the currently high use or thermal power. The development of SHP can also have a high positive impact on the country, especially in rural and remote areas that experience such issues as high voltage drops due to the long distances of transmission and regular power shortages from selective power cuts or the aging medium-voltage network. Overall, in a developing country such as Cameroon, electricity demand is always on the rise (estimated to grow at an average annual rate of 4 per cent until 2040), to the point that the development of energy infrastructure does not manage to keep up, leading to selective power cuts even in large cities.[11]

The role of foreign investment is crucial for the development of the electricity sector in Cameroon. The ongoing generation projects are mainly funded through foreign funds as the national banking system provides very limited support to investment in the sector due to high interest rates.

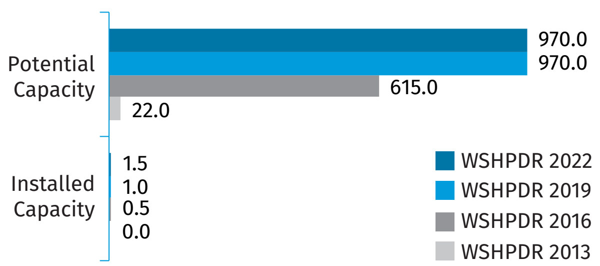
The electricity tariff system has remained unchanged since 2012. The rates are uniform all over the country and do not vary throughout the year but depend on the voltage level and the amount of energy consumed. Domestic consumers pay between 50 CFA/kWh and 99 CFA/kWh (0.077–0.150 USD/kWh).[12] Current tariffs do not represent the actual cost of electricity generation and are heavily subsidized by the Government.[13]

SMALL HYDROPOWER SECTOR OVERVIEW

There is no official definition of SHP in Cameroon, however, there is a specific regulation for power plants of up to 5 MW for rural electrification. For the purposes of this chapter, the standard up to 10 MW definition will be followed.

In 2021, the 1.48 MW Mbakaou SHP plant was commissioned (Table 1), increasing the installed SHP capacity in the country compared to the *World Small Hydropower Development Report (WSHPDR) 2019*.[14] The Mbakaou plant became the first SHP plant to be developed in the country in decades and there are plans to further boost the SHP sector. The plants developed in the early 1930s were abandoned because of the grid extension from large-scale plants, but could be rehabilitated. There might also exist other smaller-scale plants developed by non-governmental organizations, such as the 20 kW plant in Tchouadeng, however, there is no accurate information on their installed capacity and operational status.[15] The total potential is estimated at 970 MW and remains unchanged compared to the previous edition (Figure 3).[16]

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



Source: Afrik21,[14] *WSHPDR 2019*,[16] *WSHPDR 2013*,[17] *WSHPDR 2016*[18]

A detailed assessment of the SHP potential in the country is yet to be carried out, however, new SHP projects are most needed in the mountainous areas where the network experiences high voltage drops. One project under development is the 2.9 MW Ngassona plant (Table 2).

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

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Launch year*
Mbakaou Carriere	Mbakaou	1.5	15	2021

Source: Kenfack[8]

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

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Developer*	*Planned launch year*	*Development stage*
Ngassona (RUMPI)	Massaka	2.9	45	AER	N/A	Commissioning but stopped due to civil war

Source: Kenfack[8]

SMALL HYDROPOWER PROJECTS AVAILABLE FOR INVESTMENT

Table 3 shows a list of selected SHP sites available for development.

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

Name	*Location*	*Potential capacity (MW)*	*Head (m)*	*Type of site (new/refurbishment)*
Manjo	Manjo	4.6	24.3	New
Bafang	Bafang	2.9	100	New
Batie	Batie	1.6	115	New
Nchi	Maron	1.2	50	New

Source: Kenfack[8]

RENEWABLE ENERGY POLICY

The climate change policy is monitored by the Ministry of Environment in collaboration with other institutions. The Government's policies regarding renewable energy are being enhanced by new regulations under preparation, including plans and programmes relevant to SHP, especially the funds for feasibility studies.

According to the National Development Strategy 2020–2030, the country's total installed capacity is to reach 5,000 MW by 2030. The energy mix is to be based on hydropower, solar photovoltaics, gas-based thermal power and biomass. In the hydropower sector, the focus is on large-scale projects that are to be realized via public-private partnerships (PPP) or independent production. However, the Government will also encourage the construction of mini-scale hydropower to meet household demand for electricity. Legislation aimed at stimulating domestic private investment in such projects is to be developed.[19]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

SHP is governed by the same regulations as the entire electricity sector. However, specific government plans and programmes targeting SHP are highlighted in the framework for rural electrification, especially for capacities below 5 MW. There are plans to review the legislation and regulations related to titles awarded to new plants, including SHP plants. The licensing process for SHP plants is the same as for other technologies and requires all documents from the feasibility studies, including the environmental impact assessment (EIA).

COST OF SMALL HYDROPOWER DEVELOPMENT

The total cost of the Mbakaou SHP project was approximately USD 6.9 million.[20]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

While subsidies and other incentives and forms of financial support can be obtained from the Government, SHP projects usually rely on foreign funds. Many international institutions are willing to fund the development of SHP in Africa, including Cameroon.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Despite the large potential and the strong will of the Government, the development of the SHP sector has been very limited so far. The key barriers to SHP development include:

- Lack of a detailed assessment of SHP potential;
- Lack of funds for SHP development;
- Need for capacity building;
- Lack of mature projects;
- Unreliable infrastructure;
- No local production of electromechanical equipment.

The key enablers for SHP development are:

- Great SHP potential,
- SHP can provide a solution to grid unreliability in rural areas;
- Liberalized sector;
- Available grid code;
- Strong policy focus on renewable energy development, including SHP.

REFERENCES

1. World Bank (2021). Population, total – Cameroon. Available at https://data.worldbank.org/indicator/SP.POP.TOTL?locations=CM (Accessed 15 July 2022).
2. Nations Encyclopedia (n.d.). Cameroon Topography. Available at https://www.nationsencyclopedia.com/Africa/Cameroon-TOPOGRAPHY.html (Accessed 15 July 2022).
3. Nations Encyclopedia (n.d.). Cameroon - Climate. Available at https://www.nationsencyclopedia.com/Africa/Cameroon-CLIMATE.html (Accessed 15 July 2022).
4. Global Information Society Watch (2020). Cameroon. Available at https://giswatch.org/node/6248 (Accessed 15 July 2022).
5. Olivry, J.C. (1986). Fleuves et rivières du Cameroun. Paris: Editions de l'ORSTOM.
6. Kenfack, J. & Lejeune, A. (2004). Identification of hydro potential and development in Cameroon. HYDRO 2004 Proceedings, International Journal of Hydropower & Dams.
7. Eneo (2019). 2019 Annual Report. Available at http://eneocameroon.cm/pdf/Eneo2019Annual_Report.pdf (Accessed 15 July 2022).
8. Kenfack, J. (2021). Data provided by the author.
9. World Bank (2020). Access to electricity (% of population) – Cameroon. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=CM (Accessed 15 July 2022).
10. World Bank (2020). Access to electricity, rural (% of rural population) – Cameroon. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS?locations=CM (Accessed 15 July 2022).
11. Kenfack, J., Nzotcha, U., Voufo, J., Ngohe-Ekam, P.S., Nsangou J.C. & Bignom, B. (2021). Cameroon's hydropower potential and development under the vision of Central Africa power pool (CAPP): A review. *Renewable and Sustainable Energy Reviews*. Volume 151, 2021, 111596, ISSN 1364-0321. Available at https://doi.org/10.1016/j.rser.2021.111596.
12. Electricity Sector Regulation Agency (ARSEL) (2012). *Decision Tarifaire N°96 fixant les tarifs hors taxes d'électricité applicables par la sté AES SONEL de l'année 2012*. Available at http://arsel-cm.org/arsel-contenu/uploads/2019/07/Decision_Tarifaire_N_96-fixant-les-tarifs-hors-taxes-l_electricite-applicables-par-la-ste-AES-SONEL-de-l_annee-2012.pdf [in French] (Accessed 15 July 2022).
13. Energies-media (2022). Cameroun: pour ne pas appliquer le prix réel de l'électricité, l'Etat dit dépenser en moyenne 50 millions d'euros par an. Available at https://energies-media.com/cmr-pour-ne-pas-appliquer-prix-reel-electricite-letat-dit-depenser-en-moy-50-mio-deuros-par-an/ [in French] (Accessed 15 July 2022).
14. Afrik21 (2022). CAMEROON: Mbakaaou mini hydroelectric power station goes into commercial operation. Available at https://www.afrik21.africa/en/cameroon-mbakaou-mini-hydroelectric-power-station-goes-into-commercial-operation/ (Accessed 15 July 2022).
15. Réseau Climat & Développement (n.d.). *Construction de la micro centrale hydroélectrique dans la localité de Tchouandeng*. Available at http://climatdeveloppement.org/lercd/adeid-cameroun/construction-de-la-micro-centrale-hydroelectrique-dans-la-localite-de-tchouandeng/ [in French] (Accessed 15 July 2022).
16. 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.
17. 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.
18. 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.
19. Republic of Cameroon (2020). National Development Strategy 2020–2030. Available at https://snd30.cm/wp-content/uploads/2021/11/NDS30_National-Development-Strategy-2020-2030.pdf (Accessed 15 July 2022).
20. Afrik21 (2019). CAMEROON: IED Invest starts mini hydroelectric power plant construction in the north. Available at https://www.afrik21.africa/en/cameroon-ied-invest-starts-mini-hydroelectric-power-plant-construction-in-the-north/ (Accessed 15 July 2022).

Central African Republic

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KEY FACTS

Population	4,745,185 (2019)[1]
Area	623,000 km^2 [2]
Topography	The Central African Republic is a landlocked country. The lowest point in the country is the Oubagui River at 335 metres above sea level, while the highest point is Mount Kayagangiri at 1,420 metres above sea level. Rolling hills cover the centre and the south of the country. The south-east is occupied by a dense tropical forest, while the northern part of the country is flat, similar to a savanna.[3]
Climate	The climate in the Central African Republic is warm, equatorial and humid, and has defined rainy and dry seasons. Temperatures vary between 19 °C and 30 °C during the wet season, from May to October, and range from 18 °C to 40 °C in the dry season, from November to April.[4]
Climate Change	Future climate scenarios indicate a temperature increase on the order of 1.4-2.2 °C, assuming low greenhouse gas emissions, and 1.8-2.7 °C, assuming high emissions. The probability of extreme climatic hazards occurring could increase with climate change, with the main hazards consisting of heavy rains followed by floods and droughts.[4]
Rain Pattern	Heavy rainstorms frequently occur during the rainy season (May–October). Maximum annual precipitation can reach up to 1,800 mm. In the Karre Mountains the average rainfall is estimated at 1,500 mm. The north of the country is drier than the south. The average annual precipitation across the country is 1,373 mm.[4,5]
Hydrology	There are important waterways harmoniously distributed across the territory of the Central African Republic. In the north of the country, the Chari River tributaries flow. The Ubangi River is one of the most iconic in the country, forming the southern border with the Democratic Republic of the Congo. The river has numerous tributaries, such as the Chinko, Kotto, Lobaye, Mbari and Ouaka. The Mbomou River (or Bomu) represents the Ubangi River's headstream, flowing 725 km towards the west, and also contributes to forming the border with the Democratic Republic of the Congo.[4]

ELECTRICITY SECTOR OVERVIEW

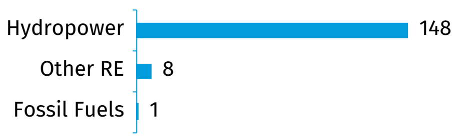
The total installed capacity of the Central African Republic in 2019 was approximately 41.2 MW, including 22.0 MW of thermal power capacity, 18.9 MW of hydropower and 0.3 MW of solar power (Figure 1).[6]

Figure 1. **Installed Electricity Capacity by Source in the Central African Republic in 2019 (MW)**

Source: African Energy Portal[6]

Gross electricity production was estimated at approximately 155 GWh at the end of 2018, and reached 157 GWh in 2019. Roughly 148 GWh were produced by hydropower in 2019, 8 GWh came from other renewable energy sources, and 1 GWh from thermal power plants (Figure 2).[7] Transmission losses are estimated at 7 per cent of the electricity produced in 2017, while distribution losses amounted to 33 per cent, which is higher than the average across Sub-Saharan Africa (between 18 and 20 per cent).[8]

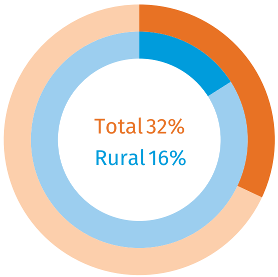
Figure 2. **Annual Electricity Generation by Source in the Central African Republic in 2019 (GWh)**



Source: AFREC[7]

Total access to electricity in the country reached 32 per cent at the end of 2019, indicating a three-fold increase since 2010.[9] However, access to electricity is unequally distributed between urban and rural areas. Thus, 55 per cent of the urban population had access to electricity in 2019 against 16 per cent of rural population.[9]

Figure 3. **Electrification Rates in the Central African Republic in 2019 (%)**



Source: World Bank[9]

Currently, the electricity supply in the Central African Republic remains lower than the demand. Furthermore, demand forecasts for the coming years predict a growth in peak demand from 80 MW in 2010 to 403 MW in 2030 in the low-growth scenario.[10]

The Ministry of Development for Energy and Water Resources (MDEWR) oversees the electricity sector in the country, with a Directorate General for Electricity established as part of the Ministry. The entity in charge of electricity production, transport and distribution is Energie Centrafricaine (ENERCA), which is a public organization founded in 1963 and owned by the Government. The two other main agencies in the Central African Republic are the Rural Electrification Agency (ACER) and the Autonomous Electricity Sector Regulatory Agency (ARSEC).[8]

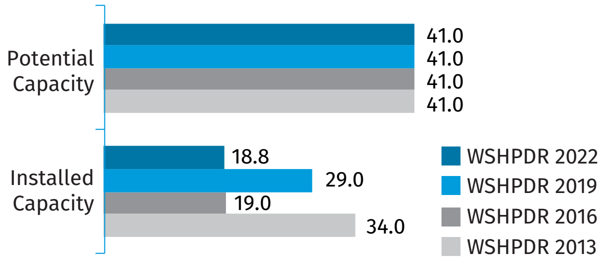
Hydropower in the country is delivered to the capital city of Bangui by two transmission lines with 17.5 MVA and 35 MVA of transit capacity. Losses in the electricity transmission and distribution system are high, due to the age of the facilities and difficulties to carry out adequate maintenance.[10]

Electricity tariffs are determined by cumulative hours of usage per month. The mixed tariffs for low-tension consumers in 2021 were 0.13 USD/kWh for usage of up to 65 hours, 0.14 USD/kWh for up to 130 hours and 0.15 USD for over 130 hours of usage. Mid-tension tariffs range from 0.044 to 0.070 USD/kWh.[11] Access to electricity in small cities and rural areas is very limited due to the price gap and the lack of infrastructure. To cover investment and operational expenses, the average electricity price should be approximately 0.2 USD/kWh.[12] This price difference induces a deficit of approximately USD 7 million per year (0.4 per cent of Gross Domestic Product).[12] The higher tariff needed is due mainly to losses in transportation and distribution as well as losses related to invoice collection and overstaffing, which are the highest in Africa, and represented 48 per cent of the budgetary deficit in the energy system in 2014.[12]

SMALL HYDROPOWER SECTOR OVERVIEW

The small hydropower (SHP) definition in the Central African Republic refers to plants of up to 10 MW. As of 2021, the total installed capacity of SHP in the country was 18.75 MW, made up of two plants: Boali I (8.75 MW) and Boali II (10.00 MW) (Table 1). It is estimated that Boali I could reach an additional capacity of up to 9.5 MW through rehabilitation works.[13] A further 10 MW was scheduled for the Boali III plant, which never was commissioned due to political instability in the country. At the current state, the Boali III plant is not complete and cannot produce electricity without a rehabilitation (dam monitoring and electro-mechanical devices). As a result of this, the total installed SHP capacity figure has decreased since the *World Small Hydropower Development Report (WSHPDR) 2019*, which counted the Boali III plant as operational. The potential estimate remains unchanged as no new data were made available (Figure 4).

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



Source: *WSHPDR 2013*,[14] *WSHPDR 2016*,[15] *WSHPDR 2019*,[16] Manso & Barnoud[17]

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

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Plant type*	*Operator*	*Launch year*
Boali I	M'bali River	8.75	52	Run-of-river	ENERCA	1955–1969
Boali II	M'bali River	10.00	64	Run-of-river	ENERCA	1976

Source: International Journal on Hydropower & Dams[13]

Potential for SHP development in the country exists in the following locations: Baboua, Bambari, Bangassou, Berbérati, Bocaranga, Bossangoa, Bouar, Bria, Carnot, Kaga-Bandoro, Kembe, Mbaîki, Ndélé, Paoua and Sibut.[18] The SHP potential is estimated at 41 MW as was reported in the previous editions of the *WSHPDR*. Additionally, 30 sites suitable for development of hydropower plants of varying sizes were identified, with capacities between 0.5 MW and 180 MW.[19] However, the site names are not known.

The United Nations Development Programme (UNDP), in collaboration with the Global Environment Facility (GEF), attempted to develop electricity generation capacities and encourage investment in Western and Middle Africa, including the Central African Republic. The project aimed to develop 36 SHP plants in the region, alongside creating an SHP network. However, in 2011 the project was cancelled for the entire region due to regional political instability.[20]

Table 2. **List of Planned Small Hydropower Projects in the Central African Republic**

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Plant type*	*Developer*	*Planned launch year*	*Stage of development*
Boali III	M'bali River	10	~30	Reservoir	ENERCA	–	Feasibility study
Boali I bis	M'bali River	–	–	Run-of-river	–	–	Feasibility study
Boali II bis	M'bali River	10	64	Run-of-river	China Gezhouba Group Corporation (CGGC)	2022?	Under construction

Source: ENERCA[10]

The incomplete Boali III plant includes an embankment dam approximately 30 metres in height and 780 metres in length. The plant is located in the central concrete block of the dam between the overflow spillways, but has never been commissioned. The dam monitoring ceased in 2010. The dam is only used, at the current time, for water flow regulation for the hydropower cascade formed by the Boali I and Boali II plants downstream. Commissioning Boali III would allow adding up to 7.5–10.0 MW of capacity without an additional territorial footprint. A preliminary safety assessment was carried out in 2019 and revealed dam security and monitoring deficiencies. In the meantime, emergency measures have been recommended and further studies have started. It can already be stated that Boali III will need large civil and electro-mechanical works in order to put the 10 MW plant in operation and to secure water storage for the entire SHP cascade of Boali I, II and III.

A new power plant named Boali II bis is presently under construction next to the existing Boali II plant. Another new project called Boali I bis is planned downstream from the existing Boali I plant, but investment for it has not been yet secured.

In addition, ENERCA plans to develop small, mini- and micro-hydropower plants for a total of 40 MW before 2030. Additionally, also some larger hydropower plants (> 10 MW) are to be developed (Lobaye, Dimoli, Lancrenon, Kotto).[10] There are also plans to provide power supply to areas in the Central African Republic from the future Mobayi SHP plant in the neighbouring Democratic Republic of the Congo.[21]

RENEWABLE ENERGY POLICY

The Central African Republic aims to reduce its emissions by at least 5 per cent and 25 per cent by 2030 and 2050, respectively, compared to its baseline emissions in the business-as-usual scenario for both years.[22] The country also aims to reduce emissions of short-lived climate pollutants, which have a significant short-term global warming potential and harmful effects on health, agriculture and ecosystems. In addition, the entire national territory is exposed to extreme climatic hazards such as droughts and heavy rains followed by flooding. The Government aims to strengthen the country's resilience to climate change in key sectors.[22]

The Central African Republic envisages a holistic approach to climate change mitigation by integrating the adjustment of national policies and strategies, the improvement of legislative and regulatory frameworks, the development of capacities and technology transfers in certain priority areas. The following energy sources are being encouraged:

- Small and micro-hydropower plants;
- Solar thermal and photovoltaic energy;
- Processes for the methanization of organic matter;
- Improved carbonization.[22]

Apart from micro-hydropower plant development, the construction of a solar power plant at Bangui, a 72 MW hydropower plant at Lobaye, a 180 MW hydropower plant at Dimoli and the Mobayi hydropower plant is also planned in the next 15 years.

Micro-hydropower and solar power are the key targeted technologies, while most renewable energy sources, such as wind and geothermal power, are still widely unexplored in the country.[22] There is existent potential for the geothermal energy, however, no studies were conducted to determine it. Wind speed measurements show promising potential at above 5 m/s and, therefore, wind power could also be a viable alternative for electricity generation in the country. The high costs associated with the development of solar power might limit its use in the Central African Republic to certain applications or services.[23]

The economic reforms initiated by the Government to encourage private investment in the Central African Republic have led to the following framework document set:

- Law No. 01.10 of 16 July 2001, instituting a charter of investments in the Central African Republic;
- Ordinance No. 05.001 of 1 January 2005 on the Electricity Code of the Central African Republic;
- Decree No. 010.092 of 18 March 2010 defining the National Energy Policy.

These instruments provide a framework for investment in the energy sector but above all offer investors the means to implement their projects.[10]

There is no specific legislation or regulation for SHP.

COST OF SMALL HYDROPOWER DEVELOPMENT

No consolidated estimates of the average cost for the development of SHP in the Central African Republic are available. Of the three small Boali plants, only the cost of Boali III can be found in open sources.[24] However, the 10 MW capacity of this plant has never been fully installed and put into operation, therefore, the cost per MW may not be relevant. Cost estimates of the largest hydropower plant projects planned over the next 15 years were used to obtain an estimate of the cost per MW of installed capacity in the Central African Republic. The average cost of hydropower installed capacity appears to be approximately 3.7 USD/MW (Table 3). Average cost of SHP development is unavailable.

Table 3. **Cost Estimation for Hydropower Plants in the Central African Republic**

	Project cost (USD million)	*Cost per unit of installed capacity (USD million/MW)*
Dimoli (180 MW)	275	1.5
Lobaye (72 MW)	180	2.5
Kotto (60 MW)	500	8.3
Boali III (10 MW)	25	2.5
Average		**3.7**

Source: UNFCCC,[22] ADF[24]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

Nowadays, the Central African Republic remains dependent on multilateral funding and donations (World Bank, African Development Bank and United Nations Industrial Development Organization) as well as bilateral financing (European Central Bank, French Development Agency and Export-Import Bank of China). This is not always a reliable way of funding projects, as they may be cancelled due to political instability in the region.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

The evolution of rainfall due to climate change varies greatly according to the scenarios, with some projecting a slight increase in annual rainfall, while others project irregular variations in precipitation. Furthermore, there are no comprehensive studies for the Central African Republic showing the potential impact of future rainfall variation on available river runoff. Temperature increases may induce larger evaporation and therefore the water balance of existing reservoirs must be reassessed, in particular that of Boali III, where the reservoir surface is large (40 km^2). Besides, the probability of occurrence of extreme climatic hazards could increase with climate change. The main hazards are heavy rains followed by floods and droughts.[25] Existing SHP plants as well as new projects will need to be rehabilitated or designed to be resilient to such hazards (as recommended by the International Hydropower Association).

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

There are multiple barriers to SHP development in the country. Some of the most important ones are the following:

- The strong monopoly in the electricity sector disincentivizes investors, increases the project-related costs and limits potential profit;
- Lack of feed-in tariffs and other support schemes for SHP development;
- Lack of trained staff able to ensure efficient operation, maintenance and management of SHP plants;
- Limited financial resources and political unrest might deter future investment in SHP;
- No standards for SHP are developed in the region, which makes current access to electricity from SHP generators unreliable and affects the prospects for future projects.[13,20]

However, due to its known benefits and potential, also efforts are being made to implement future SHP policies in the Central African Republic. The main enablers for SHP development are:

- Existing contact with organizations in the field facilitates the development strategy (ENERCA, ACER);
- Climate and topography are suitable for hydropower development;
- The will to develop SHP and rural electrification projects;
- Local presence of International Financial Institutions;
- An investment programme through ENERCA, including SHP development scheduled between 2016 and 2030.

REFERENCES

1. The World Bank (2019). *Population, total*. Available at http:// data.worldbank.org (Accessed 20 April 2021).
2. United Nations Framework Convention on Climate Change (2013). *Deuxieme communication nationale de la republique centrafricaine sous la convention-cadre des nations unies sur les changements climatiques.* Available at https://unfccc.int/sites/default/files/resource/cafnc2.pdf (Accessed 20 May 2021).
3. World Atlas (n.d.). *Central African Republic Geography. Landforms of Africa.* Available at https://www.worldatlas.com/webimage/countrys/africa/centralafricanrepublic/cfland.htm (Accessed 20 April 2021).
4. Hoogstraten et al. (n.d.). *Central African Republic. Encyclopaedia Britannica.* Available at https://www.britannica.com/place/Central-African-Republic (Accessed 20 April 2021).
5. The World Bank Group (2021). *Average Monthly Rainfall for Central African Republic from 1901 – 2016. Climate Change Knowledge Portal.* https://climateknowledgeportal.worldbank.org/download-data (Accessed 20 April 2021).
6. Africa Energy Portal (2019). *Central African Republic.* Available at https://africa-energy-portal.org/country/cen-

tral-african-republic (Accessed 4 May 2021).

7. African Energy Commission (AFREC) (2019). *African Energy Database 2019*. Available at https://au-afrec.org/publications/afrec-africa-energy-database-2019-en-fr.pdf (Accessed 4 May 2021).
8. The World Bank (2017). *Project Appraisal Document on a Proposed Grant to the Central African Republic for a Water and Electricity Upgrading Project*. International Development Association. 21st of December 2017. Available at http://documents.worldbank.org/curated/en/537671516417243128/pdf/CAR-Water-Electricity-PAD12272017.pdf (Accessed 20 April 2021).
9. World Bank (2021). *Access to electricity (in % of population).* Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=CF (Accessed 20 April 2021).
10. ENERCA (2015). *Investment plan 2016 – 2030.* https://rise.esmap.org/data/files/library/central-african-republic/CAR%20Supporting%20Documents/CC/CC%2019%20CAR%20ENERCA%20Investment%20Program%202016-2030.pdf (Accessed 20 April 2021).
11. Enerca (n.d.) *Tarif de vente d'energie en republique centrafricaine.* Available at http://enerca-rca.com/p/service-tarification (Accessed 20 May 2021).
12. World Bank (2016). *Vers une électricité abordable et des opérateurs viables en Afrique, Masami Kojima et Chris Trimble.* Available at https://openknowledge.worldbank.org/bitstream/handle/10986/25091/108555FR.pdf?sequence=11&isAllowed=y (Accessed 4 May 2021)
13. The International Journal on Hydropower & Dams (2017). *Hydropower and Dams in Africa 2017*. Africa Map. Available at http://www.hydropower-dams.com/pdfs/2017_Africa_Map.pdf (Accessed 20 April 2021).
14. 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.
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. 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.
17. Manso, P. & Barnoud, M. (2021). Information provided by the authors.
18. United Nations Environmental Programme (UNEP) (2018). *Central African Republic: Energy Consumption and Production.* April 2018. Available at https://wedocs.unep.org/bitstream/handle/20.500.11822/20497/Energy_profile_CentralAfricanRep.pdf?sequence= &isAllowed=y (Accessed 20 April 2021).
19. Andritz (2017). *Central Africa. Hydro News Africa- Special Edition*. Available at https://www.andritz.com/hydro-en/hydronews/hydropower-africa/central-africa (Accessed 20 April 2021).
20. Jonker Klunne, W. (2011). *Small hydro in Africa. Water Power Magazine*. Available at http://energy4africa.net/klunne/publications/IWP&DC_JONKER_KLUNNE_Oct_2011_Small_hydro_Africa.pdf (Accessed 20 April 2021).
21. Afrik 21 (2020). *News on the green economy, the environment and sustainable development in Africa*. Available at https://www.afrik21.africa/en/car-drc-afdb-finances-the-rehabilitation-of-the-boali-hydroelectric-power-plant/ (Accessed 20 April 2021).
22. United Nations Framework Convention on Climate Change (UNFCCC) (2015). *Central African Republic: Intended Nationally Determined Contribution (INDC). September 2015.* Available at https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/Central%20African%20Republic/1/CPDN_R%C3%A9publique%20Centrafricaine_EN.pdf (Accessed 20 April 2021).
23. The Renewable Energy and Energy Efficiency Partnership (REEEP) (2012). *Central African Republic. Policy and Regulatory Overview*. Available at https://www.reeep.org/central-african-republic-2012 (Accessed 20 April 2021).
24. African Development Fund (ADF) (1994). *Rapport d'achèvement du projet de barrage hydro-électrique de Mbali.* Available at https://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/ADF-BD-IF-96-33-FR-SCANNEDIMAGE.178.PDF (Accessed 20 April 2021).
25. United Nations Framework Convention on Climate Change (UNFCCC) (2015). *Intended nationally determined contribution (INDC), Central African Republic.* Available at https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Central%20African%20Republic%20First/INDC_R%C3%A9publique%20Centrafricaine_EN.pdf (Accessed 20 April 2021).

Congo

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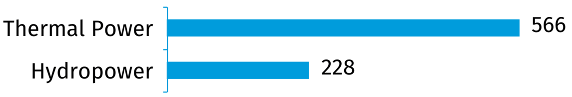
KEY FACTS

Population	5,518,000 (2020)[1]
Area	342,000 km[2]
Topography	The coastal area is a plain approximately 40 kilometres wide and 160 kilometres long between Gabon and Cabinda.[2] There are three dominant mountain ranges in Congo. The Mayombé Massif, or Mayumbe, is an old low-lying chain of mountains with deep river gorges that extends from the mouth of the Congo River in the south and to the Kouilou-Niari River in the north and parallels the coast.[2] The neighbouring Niari region hosts a valley and another mountain range, Chaillu Massif, reaching elevations of 400-700 metres above sea level before extending into south Gabon.[2] Beyond the Niari Valley lies a series of plateaus at approximately 490 metres. A vast plain occupies the north-eastern part of the country. The highest peak is Mont Nabemba (1,020 metres) located in the north-west.[2]
Climate	The climate in Congo is mostly hot and humid with heavy precipitation, due to the country's geographical location and the coastal plain. The north of the country has an equatorial climate, while the south has a tropical one. Average temperatures vary between 24 °C and 28 °C throughout the year.[3]
Climate Change	Congo is projected to see a 1 °C rise in mean annual temperatures by 2050 and to experience increased heat wave durations. The area will also see an increase in annual rainfall by 2046-2065 and an intensification of rainfall.[3]
Rain Pattern	Precipitation is abundant but varies throughout the year and across regions, with the equator crossing the country in the middle. The north of Congo experiences a dry season from November to April and a rainy season from April to November, whereas in the southern part the rainfall pattern is the exact opposite. Annual precipitation in the country averages 1,200 mm but often surpasses 2,000 mm. In the north, average annual precipitation ranges between 1,500 and 2,000 mm, while in the south precipitation can be lower than 1,500 mm and reach 1,200 mm near the coast.[2]
Hydrology	The major river is the Congo River. Its main northern tributary, the Ubangi River, flows southwards and forms the country's eastern border. The largest right-bank tributaries of the Congo River include the Sangha, the Likouala, the Alima, the Nkeni, the Lefini, the Djoue and the Foulakari.[2] The Kouilou-Niari is another major river that flows south-west from its source in the plateau region to Kayes and into the Atlantic. On the stretch from the Niari valley to Makabana it is known as the Niari River.[2]

ELECTRICITY SECTOR OVERVIEW

From 2018 to 2019, overall electricity generation in Congo increased by 5 per cent, however, most of this generation increase was made up by thermal power generation from the gas-fired Congo Power Plant (Centrale Electrique du Congo, CEC) Pointe-Noire (Figure 1).[4] In contrast, hydropower generation decreased by 22 per cent, from 1,120 GWh in 2018 to 872 GWh in 2019. This decrease mainly came from the Imboulou hydropower plant, whose generation in 2019 decreased by more than 30 per cent compared to 2018 (Table 1).[4]

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



Source: E2C (a.k.a E²C.SA)[4]

*Translated from French by Tamsyn Lonsdale-Smith, ICSHP

Table 1. **Annual Electricity Generation by Power Plant in Congo in 2015–2019 (GWh)**

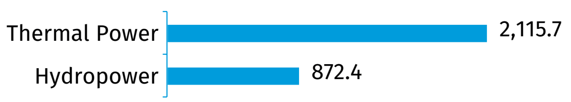
Power plant	*Installed capacity (MW)**	*Type*	*Annual generation (GWh)*				
			2015	*2016*	*2017*	*2018*	*2019*
Imboulou	120	Hydropower	703.5	684.4	702.8	645.3	433.1
Moukoukoulou	74	Hydropower	394.5	430.1	473.9	449.0	413.5
Liouesso	19	Hydropower	N/A	12.5	26.4	25.7	25.8
Djoué (non-operational since 2007)	15	Hydropower	-	-	-	-	-
CEC Pointe-Noir	484	Thermal power	1,434.5	1,643.5	1,646.7	1,719.2	2,115.3
Djeno (non-operational since 2018)	50	Thermal power	N/A	N/A	N/A	-	-
Brazzaville	32	Thermal power	4.8	2.2	2.0	3.0	0.4
Total	**794**		**2,537.3**	**2,772.7**	**2,851.8**	**2,842.2**	**2,988.1**

Source: E2C,[4] LCA,[5] ANDRITZ HYDRO,[6] E2C[7]

Note: *As of 2020.

As of February 2020, the installed capacity of Congo was at least 794 MW. Of this, thermal power accounted for approximately 71 per cent and hydropower for 28 per cent (Figure 2).[5,6,7] The renovation works of the gas-fired power plant CEC Pointe-Noire were completed in February 2020, increasing the plant's installed capacity to 484 MW and, therefore, the country's total installed thermal power capacity to 566 MW.[8] The total hydropower capacity is 228 MW, including the 15 MW of the non-operational Djoué plant. The largest hydropower plant in the country is the Imboulou plant of 120 MW, which came online in 2010 and supplies electricity to the city of Brazzaville. In addition to its domestic capacity, Congo imports 50 MW from the Inga hydropower plant in the Democratic Republic of the Congo (DRC).[5,6] The electricity grids of the DRC and the Republic of Congo are interconnected.

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

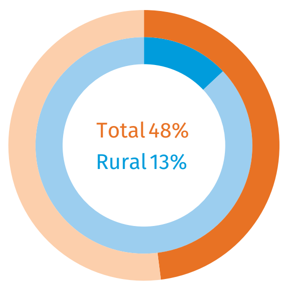


Source: LCA,[5] ANDRITZ HYDRO,[6] E2C[7]

More than half of the country's total installed capacity comes from the gas-fired power plant at Pointe-Noire (Table 1). The role of this plant is particularly important during the dry season when generation by hydropower plants decreases. The plant has three turbines, which have operated in parallel with the Inga hydropower plant in the DRC since 2015. The Government expanded the plant with the addition of a third 170 MW turbine. The two pre-existing turbines were at a capacity of 314 MW (each one was upgraded from 150 to 157 MW), bringing the total capacity of the plant up to 484 MW.[7] The work for this project commenced in 2019 and was completed on 18 February 2020.[8] The plant has the potential to reach up to 1 GW in the future with efficiency improvements and the addition of a proposed fourth turbine.[7] The Djeno thermal power plant has not been in operation since the transfer of its operating capacity to Kouilou Power SA in 2018.[9]

There are four hydropower plants in the country, however, only three of them are operational. In 2018, as part of the reforms undertaken in the sector, the Government launched the bidding for tenders for hydropower projects. The Djoué hydropower plant has not been functioning since 2007 due to flooding and subsequent rehabilitation work.[6] In 2018, Yunnan Linkun Investment Group agreed to rehabilitate the plant.[10] According to other sources, the task of completing a feasibility study and providing technical assistance for upgrading the power plant from 15 MW to 30 MW was awarded to Studio Pietrangeli Consulting Engineers.[11,14] It is unclear if any of this planned rehabilitation, extension and modernization work at the Djoué power plant is continuing as planned. The most recently constructed hydropower plant, the Liouesso plant, with a capacity of 19.2 MW, was commissioned in the northern Sangha Department on the Sangha River in 2017.[12] The installation of this plant aimed to foster economic activity in the region. Previously, users had access to electricity for only a couple of hours per day.[12]

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



Source: World Bank[13]

In 2019, 48 per cent of the country's population was connected to the electricity grid, and only 13 per cent in rural areas (Figure 3).[13] In comparison, 9 per cent of the rural population had electricity access in 2010, mostly due to access to mini-grids fuelled by diesel or gasoline.[14] The electricity demand of Congo has been growing and is expected to exceed 1 GW by 2027.[15] In particular, the demand of the Pointe-Noire special economic zone is expected to reach 700 MW, the demand of the city of Brazzaville 250 MW and the demand of the potash mines in Kouilou 150 MW.[15] With this in mind, the Government aims to increase the electricity generating capacity of the country.

The projects under development include the Chollet hydropower plant, with a capacity of 600 MW, which is to be jointly developed by Cameroon and Congo. The plant will be located in the Ngbala region of Congo on the Dja River and will make up part of the Central Africa Power Pool (CAPP). The project envisages the construction of electricity lines between the two countries and will interconnect their electricity networks. Congo will be the major beneficiary of the project, receiving 300 MW of the capacity, Cameroon will receive 60 MW and the remaining 240 MW will go to neighbouring countries. The contract on the construction of the plant was signed in 2010, however, little progress had been made until 2017 when the Intergovernmental Committee of the two countries met to confirm the intention to accelerate the development of the project.[16] Following another meeting in 2020, the technical and feasibility studies were scheduled to take place during the first quarter of 2021, after which the questions of financial mobilization and construction of the project are to be addressed.[17] Another project under consideration is the 80–100 MW hydropower plant of Mourala, on the Louessé River.[18] The feasibility study for the Mourala project has been completed and as of 2019 research for financing was underway.[19] A number of other potential hydropower projects are currently under consideration.[20]

On 9 April 2019, the Government of Congo and the Ministry of Energy and Hydraulics signed a memorandum of understanding with the China Railway 20th Bureau Group Co Ltd (CR 20GC) to develop the Gorges de Sounda hydropower project in the Kouiloi department.[21] The memorandum of understanding defined the manner in which the project will be implemented and that CR 20GC will lead the feasibility studies, including environmental and social impact reports, thereby completing preliminary studies undertaken by the International Finance Corporation (IFC). In November 2017, the IFC recommended a capacity between 486 MW and 616 MW and an optimal concept at a 70 metre full supply level, in consideration of the environmental and social impact of the project.[22,23] The studies performed by CR 20GC were expected to propose a higher capacity estimate than that proposed by the IFC study while minimizing the environmental and social impact. This new study is in response to the Government's aim to maximize the potential of the project and explore optimal options between 80 and 100 metres of full supply level.

The electricity sector of Congo is regulated by the Ministry of Energy and Hydraulics, and the National Agency for Rural Electrification (Agence Nationale d'Electrification Rurale, ANER) oversees the electrification of rural areas. In 2003 and after the creation of the Agency for the Regulation of the Electricity Sector (l'Agence de Régulation du Secteur de l'électricité, ARSEL), the sector was liberalized, legally ending the state-owned monopoly. However, a major role in the electricity market was still played by the state-owned company the National Electricity Company (Société Nationale d'Electricité, SNE), which was founded in 1967 through Law No. 67. SNE produced, transported, distributed and marketed electricity and maintained electrical infrastructure. After liberalization, it still held monopoly over electricity production until 2018.[24] The electricity sector opened up to private investors in 2018, and international financial institutions such as the International Monetary Fund and the World Bank have supported privatization, competition and economic reforms in the sector.[22]

In February 2018, the Government approved the plan to dissolve the SNE as well as the National Water Distribution Company (Societe Nationale de Distribution d'Eau, SNDE) since they proved to be inefficient and failed to reach sufficient profitability despite state investment. Following the sector reforms, the Heritage Company for the Electricity Sector (Société de Patrimoine pour le secteur de l'électricité, SPSE) was created. The creation of two other government agencies also ensued: the Society for Electricity Transportation (La Société de Transport de l'électricité, STE) and the Heritage Society for the Water Sector (La Société de Patrimoine pour le Secteur de l'Eau, SPSEA), which manage the sector based on public service concession contracts between the Government and public and private operators.[25] As of 2021, CEC S.A. is the main electricity producer, owned 20 per cent by ENI and 80 per cent by the state, and operates independently after attaining a licence from the Ministry of Energy and Hydraulics.[24] The reform of the electricity sector is expected to attract investment into the sector, and boost the struggling economy.[27]

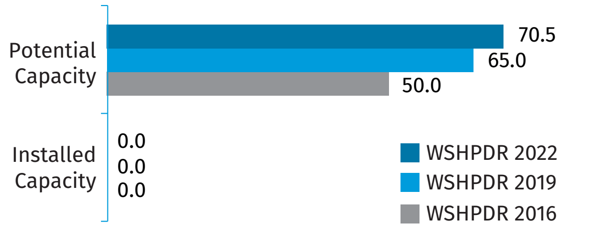
Electricity in Congo is transmitted via 110 kV and 220 kV lines and distributed via 30 kV, 20 kV, 6.6 kV, 380 V and 220 V lines. Following Decree No. 681 of 19 March 1994 by the Ministry of Commerce, Consumption and Small and Medium Enterprises, electricity tariffs in Congo have been unified across the country and divided into three categories: low voltage, public lighting and medium and high voltage. Electricity prices vary depending on these three categories and the level of consumption regardless of the type of consumer. Low voltage tariffs vary between 31.2 XAF/kWh (0.019 USD/kWh) and 49.08 XAF/kWh (0.030 USD/kWh).[28] Small producers outside of the national grid may negotiate prices with the consumers, according to Article 20 of the National Electricity Code.[14]

SMALL HYDROPOWER SECTOR OVERVIEW

There is no official definition of small hydropower (SHP) in Congo, therefore, this report uses the standard definition of SHP as hydropower plants with a capacity of up to 10 MW.

At present, Congo has four large hydropower plants. The smallest plant is at a capacity of 19.9 MW, the Liouesso plant, was commissioned in 2017 and constructed by the China Gezhouba Group.[29] The potential for hydropower development in the country has been estimated at approximately 14 GW, as defined by Government Decree No. 2010-822 of 31 December 2010.[29,30] The technical potential has been estimated at 3.9 GW, of which approximately 4 per cent has been developed.[25] The main potential for hydropower development is located in the Plateaux region, the Sangha region, Cuvette and Cuvette-Ouest. The potential for SHP development is assumed to be quite significant, but there are no publicly available feasibility studies and no ongoing SHP projects in Congo at this time. Compared to the results of the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed SHP capacity has not changed and stayed at zero, whereas the potential capacity increased by 9 per cent due to revised calculations (Figure 4).

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



Source: *WSHPDR 2013*,[33] *WSHPDR 2016*,[34] *WSHPDR 2019*[35]

A Global Environment Fund–funded United Nations Development Programme (UNDP) project, Small Hydropower-based Mini-grids for Rural Electrification in Congo-Brazzaville, is planning 12 feasibility studies, but the project was still in its infancy as of 2019 and faced technical setbacks due to management and satellite data interruptions.[31]

The Hydropower Atlas developed by the UNDP in 2008 identified 17 potential SHP sites with capacities ranging between 6 kW and 6 MW and a combined capacity of almost 21 MW (Table 3).[18] Another study identified 10 potential sites with estimated capacities ranging between 5 MW and 10 MW with a combined capacity of at least 50 MW.[31] Based on these two estimates, the potential of SHP in Congo should be at least 70.5 MW. An additional feasibility study of seven potential mini-hydropower sites was proposed by the African Development Bank, and six feasibility studies are currently underway under the African Development Bank's Light up and Power Africa programme and expected to be approved for 2021.[32]

Although SHP could be used to meet the needs for electricity in rural areas as well as feed into the national grid, serving as an efficient and environmentally sustainable source, the sector has faced numerous barriers hindering its development. The gaps in the regulatory framework in relation to SHP projects, the lack of local skills to install, operate and maintain an SHP plant as well as of local technology make the sector less attractive than other power projects.[14] Another major barrier is low electricity tariffs.[34]

SMALL HYDROPOWER PROJECTS AVAILABLE FOR INVESTMENT

Table 2 offers details on SHP projects available for development in the country.

Table 2. **List of Selected Small Hydropower Sites Available for Development**

Name	*Location*	*Potential capacity (MW)*	*Head (m)*	*Type of site (new/refurbishment)*	*Type of project*
Mambouana	Lekoumou	0.43	424	New	Run-of-river
Assoumoundele	Sangha	6.18	202	New	Reservoir
Kimpanzou	Pool	5.51	380	New	Run-of-river
Kimbanda	Pool	4.02	250	New	Dam
Bela	Pool	3.18	260	New	Reservoir

Source: UNDP[14]

Note: Data from 2008.

RENEWABLE ENERGY POLICY

The Government envisages the development of renewable energy sources available in the country, including hydropower, biomass, solar power and wind power, in particular in remote areas. However, no policy or strategy promoting renewable energy has been developed to date. As a result, the available resources remain untapped.

The major laws and regulations of the electricity sector include:

- Law No. 14/2003 of 10 April 2003, defining the Electricity Code and liberalizing the market;
- Law No. 15/2003 of 10 April 2003, establishing the National Agency for Rural Electrification (ANER);
- Law No. 16/2003 of 10 April 2003, establishing the Agency for the Regulation of the Electricity Sector (ARSEL);
- Law No. 17/2003 of 10 April 2003, establishing the Development Fund of the Electricity Sector;
- Decree No. 2010-822 of 31 December 2010, approving the development strategy for the sectors of electricity, water and sanitation;
- Law No. 22-2018 of 13 June 2018 establishing the dissolution of the National Electricity Company (SNE);
- Decree No. 295-2018 creating the new Electrical Energy Society of Congo (Société Energie Electrique du Congo, E2C).

In accordance with the Electricity Act of 2013, independent power producers are required to obtain a licence. However, for small-scale projects of electricity generation, transmission, distribution and sales in rural areas, it suffices to obtain an authorization by the corresponding Ministry. Every project within the electricity sector is obliged to conduct an environmental impact study prior to the commencement of the project, according to Article 12 of the national Electricity Code. Financial incentives for the sector are non-existent.

COST OF SMALL HYDROPOWR DEVELOPMENT

The cost of transportation and distribution to remote villages can be quite high, especially in densely forested areas and when coupled with low demand, which lends the argument that in Congo hydropower investments should be made in close proximity to demand. In general, it costs 50,000 USD/km for 33 kV lines, and distribution costs can be as much as USD 2,000 per connection.[14] For this reason, the development of SHP is most economically feasible at the local village level and if connected to mini-grids.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

The change in precipitation patterns and resulting hydrological shift in the country affect the potential of SHP development, mainly due to the risk of low water levels and unpredictability. There are frequent floods in the Congo Basin (Mossaka) and low-lying areas of the country.[32] Decreased rainfall leading to aquifer deficit has affected Point-Noire, putting pressure on the city's water supply and disrupting the operation of hydropower plants in the Niari Valley.[32]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Large hydropower is predominant in Congo, and the general trend in governance following the energy sector reforms in 2018 is to open up the sector to private competition. The Government is actively seeking maximum exploitation of power capacity and potential, despite preliminary environmental and social feasibility studies recommendations, as demonstrated by the rejected IFC study.

The SHP sector in Congo is currently non-existent, although several small-scale plants are in the planning phase due to international development programmes and investment. Meanwhile, the domestic hydropower sector has continued to invest in large-scale hydropower projects and thermal electricity generation. Due to the distribution and connection costs, SHP development is best suited to local, village-level projects.

The main obstacles to the development of SHP in Congo include:

- Low rainfall in dry season due to climate change that will decrease hydropower production, leading to decreased stability;[3]
- Gaps in the legal, regulatory and institutional framework;
- Lack of local skilled workforce to design, install, operate and maintain SHP plants;
- Lack of tax exemptions on SHP equipment;
- Low electricity prices;
- Low awareness of SHP among the population;
- Expensive transmission costs through densely forested areas;
- The country's current financial situation minimizes the potential for future financing programmes.[29]

Despite these barriers, Congo has significant water resources for the development of SHP. The national electrification policy is keen to develop this potential to serve rural areas remote from the national electricity grid.

The main enablers for the development of SHP in Congo include:

- Available SHP potential;
- Increased rainfall and intensity in wet seasons due to climate change could increase hydropower production;
- Existing interest from international development institutions in SHP development in the country;
- Liberalized energy market with a relatively restrained regulatory landscape.[3]
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REFERENCES

1. United Nations, Department of Economic and Social Affairs, Population Division (2019). *WPP2019_POP_F01_1_TOTAL_POPULATION_BOTH_SEXES*, World Population Prospects 2019, Online Edition. Rev. 1. Available at https://population.un.org/wpp/Download/Standard/Population/ (Accessed 15 February 2021).
2. Encyclopaedia Britannica (2018). *Republic of the Congo*. Available at https://www.britannica.com/place/Republic-of-the-Congo (Accessed 15 February 2021).
3. United States Agency for International Development (USAID) (2018). *Climate Risks in the Central Africa Regional Program for the Environment (CARPE) and Congo Basin. Fact Sheet.* Available at https://www.climatelinks.org/resources/climate-risks-central-africa-regional-program-environment-carpe-and-congo-basin (Accessed 13 February 2021).
4. Electrical Energy Society of Congo (E2C) (2019). Internal document transmitted to the Ministry of Energy and Hydraulics for energy statistics database. Provided by chapter authors.
5. Logistics Capacity Assessment (LCA) (2017). *Republic of the Congo Additional Services.* Available at http://dlca.logcluster.org/display/public/DLCA/3.6+Republic+of+the+-Congo+Additional+Services;jsessionid=1CB00C8C47D-99303283F418BC7 F79BF3#id-3.6RepublicoftheCongoAdditionalServices-ElectricityandPower (Accessed 15 February 2021).
6. ANDRITZ Hydro (2017). *HYDRONEWS Afrique*. Magazine d'ANDRITZ HYDRO, 06-2017 Français, Available at https://www.andritz.com/resource/blob/227922/a2e-

2d46e924531e9fb6b071ffd8ec1dd/hy-hydro-news-africa-fr-data.pdf (Accessed 15 February 2021).
7. Electrical Energy Society of Congo (E2C) (2020). *Centrale Electrique du Congo (CEC).* 21 August 2020. Available at https://e2c.cg/production/Centrale%20%C3%A9lec-trique%20du%20Congo%20%28CEEC%29 (Accessed 13 February 2021).
8. African Energy (2020). *Congo adds new CEC unit but falls short on grid infrastructure.* 27 February 2020. Available at https://www.africa-energy.com/article/congo-adds-new-cec-unit-falls-short-grid-infrastructure (Accessed 13 February 2021).
9. Agence d'Information d'Afrique Centrale (2020). *Centrale électrique de Djeno : les ex-agents sollicitent l'implication des autorités pour son fonctionnement.* 11 February 2020. Available at https://www.adiac-congo.com/content/centrale-electrique-de-djeno-les-ex-agents-sollicitent-limplication-des-autorites-pour-son (accessed 24 February 2021).
10. Energies Media (2018). *Congo: le groupe chinois Yunnan Linkun en lice pour des projets énergétiques dont une centrale à gaz de 2200 MW.* 3 September 2018. Available at https://energies-media.com/congo-yunnan-linkun-lice-projets-energie-dont-centrale-a-gaz/ (Accessed 15 February 2021)
11. Studio Pietrangeli (n.d.). *Djoué Hydropower (Congo): Engineering for upgrade of the existing hydropower plant.* Available at https://www.pietrangeli.com/djoue-hydropower-plant-congo-africa (Accessed 2 February 2021).
12. Bayiha, W. (2017). *Une centrale électrique à Liouesso pour "désenclaver" le nord du Congo.* Africanews, 31 May 2017. Available at http://fr.africanews.com/2017/05/31/unecentrale-electrique-a-liouesso-pour-desenclaver-le-nord-du-congo (Accessed 15 February 2021).
13. World Bank (2018). *Access to electricity (% of population).* Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=CG (Accessed 15 February 2021).
14. United Nations Development Programme (UNDP) (n.d.). *Titre du projet : Mini réseaux hydroélectriques pour l'électrification rurale au Congo-Brazzaville.* Available at https://info.undp.org/docs/pdc/Documents/COG/PIMS%20 4685%20PRODOC%20final%20version%20FR%20Microhydro.pdf (Accessed 15 February 2021).
15. Mapanga, G. (2017). *Congo: Les besoins en énergie dans les dix prochaines années seront de 1000 mégawatts contre 600 mégawatts actuellement.* Les Echos du Congo Brazzaville, 6 November 2017. Available at https://lesechos-congobrazza.com/economie/3693-congo-les-besoins-en-energie-dans-lesdix-prochaines-annees-seront-de-1000-megawatts-contre-600-megawatts-actuellement (Accessed 13 February 2021).
16. Etoundi, E. (2018). *Barrage hydroélectrique de Chollet: Entre espoirs et inquiétudes.* Afrique Progrès Magazine, 12 April 2018. Available at http://www.afriqueprogres.com/economie/5221/ barrage-hydroelectrique-de-chollet-entre-espoirs-et-inquietudes (Accessed 15 February 2021).
17. Africa Energy Portal (2020). *Cameroon-Congo: the 600 MW hydroelectric project on the Dja/Ngoko river relaunched in 2021?* 30 October 2020. Available at https://africa-energy-portal.org/news/cameroon-congo-600-mw-hydroelectric-project-djangoko-river-relaunched-2021 (Accessed 15 February 2021).
18. United Nations Development Programme (UNDP) (n.d.). *Small Hydropower-based Mini-grids for Rural Electrification in Congo-Brazzaville*. Available at https://info.undp.org/docs/pdc/Documents/COG/PRODOC%20PNUD%20 Small%20Hydropower.pdf (Accessed 13 February 2021).
19. Pool Énergétique de l'Afrique Centrale (2019). Etat d'Avancement des projets au portefeuille du PEAC 2019. Available at http://www.peac-ac.org/pdfs/Portefeuille_de_projet_PEAC_2019.pdf (Accessed 24 February 2021).
20. Hydropower & Dams (2017). *Hydropower & Dams in Africa 2017.* Available at http://www.hydropower-dams.com/pdfs/2017_Africa_Map.pdf (Accessed 13 February 2021).
21. Embassy of Congo, France. (2019). La China Railways 20 propose de construire le barrage de Sounda (600 MW). *Press Release,* 11 April 2019. Available at https://www.ambacongofr.org/index.php/l-ambassade/actualites/324-la-china-railways-20-propose-de-construire-le-barrage-de-sounda-600-mw (Accessed 13 February 2021).
22. World Bank (2019). *Country Partnership Framework for the Republic of Congo for the Period Fy20-Fy24 (Report No. 126962-CG)*, 12 November 2019. Available at http://documents1.worldbank.org/curated/en/763151576206076142/pdf/Congo-Republic-of-Country-Partnership-Framework-for-the-Period-FY20-FY24.pdf (Accessed 15 February 2021).
23. Cauldwell, A. (2017). *A New Landscape Approach to Assess Alternative Hydropower Opportunities*. Powerpoint presented at the IAIA Special Symposium: Mainstreaming the Mitigation Hierarchy in Impact Assessment. Available at https://conferences.iaia.org/wdc2017/presentations/A%20 Cauldwell%20New%20Approach%20to%20Assess%20Alternative%20Hydropower.pdf (accessed 24 February 2021)
24. Energie Electrique du Congo (E2C) (n.d.). *Historique.* Available at https://e2c.cg/node/19 (Accessed 13 February 2021).
25. ANDRITZ Hydro (2017). Republic of Congo - Moving forward with hydropower. *Hydro News Africa - Special editon.* Available at https://www.andritz.com/hydro-en/hydronews/hydropower-africa/rep-of-congo (Accessed 13 February 2021).
26. CERBAC (2018). Congo-B : Privatisation de la SNE et de la SNDE. *Centre d'Etudes et de Recherches du Bassin du Congo,* 21 February 2018. Available at http://companehemie.over-blog.com/2018/02/congo-b-privatisation-de-la-sne-et-de-la-snde.html (Accessed 13 February 2021).
27. Elion, C. (2018). *Congo Republic plans to dissolve state power*, 101 1.1. MIDDLE Africa water utilities. Reuters, 2 February 2018. Available at https://www.reuters.com/article/us-congorepublic-utilities/congo-republic-plans-to-dissolve-state-power-water-utilitiesidUSKBN1FM2JP (Accessed 15 February 2021).
28. Energie Electrique du Congo (E2C) (n.d.). Tarifs d'Électricité. Available at https://e2c.cg/node/45 (Accessed 13 February 2021).
29. Harris, M. (2017). *Congo Republic's 19.9-MW Liouesso hydroelectric project inaugurated.* Hydro Review, 30 May 2017. Available at https://www.hydroreview.com/world-regions/congo-republic-s-19-9-mw-liouesso-hydroelectric-project-inaugurated/#gref (Accessed 18 February 2021).
30. Décret n° 2010-822 du 31 décembre 2010. Available at http://extwprlegs1.fao.org/docs/pdf/con105795.pdf (Accessed on 15 February 2021)

31. Global Environment Fund (2019). *GEF Project Implementation Report (PIR): Small Hydropower-based Mini-grids for Rural Electrification (GEF Project ID 5424).* Available at https://www.thegef.org/project/small-hydropower-based-mini-grids-rural-electrification (Accessed 18 February 2021).
32. African Development Bank Group (2019). *Congo Country Strategy Paper 2018 - 2022*. Available at https://www.afdb.org/en/documents/document/congo-country-strategy-paper-2018-2022-107414 (Accessed 13 February 2021).
33. 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.
34. 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.
35. 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.

Democratic Republic of the Congo

International Center on Small Hydro Power (ICSHP)

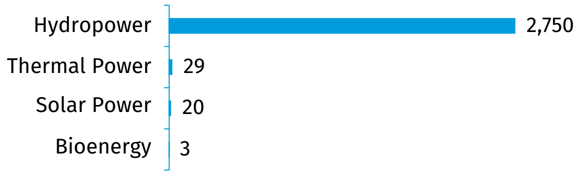
KEY FACTS

Population	89,561,404 (2020)[1]
Area	2,345,410 km^2 [2]
Topography	The Democratic Republic of the Congo (DRC) is a large and topographically diverse country with high plateaux, mountain ranges, a major valley, a large river basin and a low coastal plain. The Congo Basin, a large rolling plain at the centre of the country, has an average elevation of approximately 520 metres above sea level. The highest elevation in the country is at Margherita Peak, part of the Ruwenzori Mountain Range at the border with Uganda, with an estimated elevation of approximately 5,109 metres. This mountain range is part of the Western Rift Valley, which forms the country's eastern borders and includes the lakes Kivu, Edward, Albert, Mweru and Tanganyika. The active volcanic Virunga Mountains are also found in this area, at the border with Rwanda.[3]
Climate	The DRC has a largely equatorial climate with variations across the country's vast land area. The north and west of the country are hot and humid while the south, east and central areas are cooler and drier. The country's climate is driven by the seasonal migration of the Intertropical Convergence Zone across the equator. The mean annual temperature in the country is 24.4 °C. The northern and central to south-western areas average between 24 °C and 25 °C and the south and south-eastern savannah areas average between 22 °C and 23 °C. The tropical climate zones in the country experience a dry season (from April to October) and a rainy season (from November to March).[4,5]
Climate Change	Over the last 30 years, temperatures have been observed to increase by an average of 0.17 °C per decade. It is projected that the average temperature will increase by 1.7-4.5 °C and the average precipitation could increase by up to 8 per cent from the base period (1971–2000) by the end of the 21st century. Longer periods of dry seasons are also expected. However, no significant variations in rainfall patterns have been observed in the DRC.[5,6]
Rain Pattern	The DRC experiences a mean annual precipitation of 1,504 mm, with between 140 and 160 rainy days a year on average. In the central Congo Basin, precipitation averages between 1,800 mm and 2,200 mm a year. In the eastern regions, precipitation can reach 3,000 mm per year. In the coastal areas, the climate is drier and precipitation averages 810 mm a year.[6]
Hydrology	The DRC is home to over half of the African continent's surface water reserves and about one quarter of the continent's water resources, making it the most water-rich country in Africa. Approximately 30 per cent of the country's water resources originates from neighbouring countries. The Congo Basin covers approximately 98 per cent of the country, is the second largest in the world and hosts the world's deepest river, the Congo River. The other 2 per cent of the country is covered by the Nile Basin, which contributes approximately 20 per cent of the White Nile's flow. The DRC is also home to various rivers and lakes that it shares with its neighbouring countries, including the lakes Edward, Kivu, Albert and Tanganyika.[7]

ELECTRICITY SECTOR OVERVIEW

The main sources of electricity in the Democratic Republic of the Congo (DRC) are hydropower and thermal power, accounting for 99 per cent and 1 per cent, respectively, of total production, which amounted to 9,990 GWh in 2019. A further 0.1 per cent was from solar power. Production from hydropower, non-renewable thermal power and solar power amounted to 9,855 GWh, 107 GWh and 28 GWh, respectively, in 2019 (Figure 1).[8]

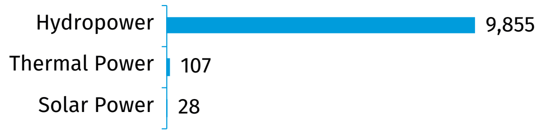
Figure 1. **Annual Electricity Generation by Source in the DRC in 2019 (GWh)**



Source: IRENA[8]

In 2020, the total installed capacity in the DRC was 2,802 MW with hydropower, non-renewable thermal power and solar power contributing 98 per cent, 1 per cent, 0.7 per cent and 0.3 per cent respectively. Installed hydropower capacity was approximately 2,750 MW, thermal power capacity was 29 MW, solar power capacity was 20 MW and bioenergy capacity was 3 MW in 2020 (Figure 2).[8]

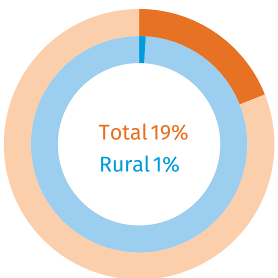
Figure 2. **Installed Electricity Capacity by Source in the DRC in 2020 (MW)**



Source: IRENA[8]

The electrification rate in the DRC was 19 per cent in 2020, with 49 per cent access in urban areas and 1 per cent in rural areas (Figure 3), making the DRC one of the countries with the lowest rates of electrification in the world.[9] There are significant issues of electricity shortage in the country, which make even customers connected to the national grid experience frequent blackouts. These issues are mainly caused by ageing and faulty equipment and lack of regular maintenance. Programmes for the rehabilitation of equipment were designed but have not succeeded in yielding considerable positive results yet mainly due to a gap in key skills and unrealistic objectives given the budgetary constraints.[10]

Figure 3. **Electrification Rate in the DRC in 2020 (%)**



Source: Energy Capital and Power[9]

The energy sector in the DRC is under the responsibility of the Ministry of Energy and Hydraulic Resources (MEHR), while the national utility responsible for the generation, transmission and distribution of electricity is the Société Nationale d'Électricité (SNEL). Due to the Government's promise to decentralize the electricity sector, private electricity operators have emerged, though remain regulated by SNEL. These include Virunga SARL, SOCODEE and BBOXX.[10]

Over the years, the electricity grid and transmission systems have been improved and enhanced. The high-voltage (HV) transmission system was 2,475.7 kilometres in 1970. This HV transmission system had extended to 5,260.7 kilometres by 1982, and by 2012 the distance serviced by the HV transmission network was 5,788 kilometres. In 2015, a second transmission system (400 kV) connecting Inga and Kinshasa and covering a distance of 277.3 kilometres was completed. This transmission network was financed by the European Investment Bank to reinforce and secure electricity generation for the city of Kinshasa. As of 2020, the total HV transmission system was 6,975.36 kilometres, including 1,774 kilometres of very HV direct current electric power transmission system extending from Inga in the west to Kolwezi in the south. There are several projects underway that aim to build transmission lines to neighbouring countries, including Uganda, Angola and Zambia. One of these projects is the proposed DRC–Angola Transmission Interconnector, which could link the two countries through a 250-kilometre 400 kV transmission line.[11,12,13,14]

There are several projects in various stages of completion to develop the energy sector in the DRC and increase access to electricity. These include the KivuWatt project, which has been partially completed and exploits the natural methane reserves of the Lake Kivu, shared with Rwanda, for electricity generation. There is also a concerted effort to accelerate the development of gas for domestic use, which could prove to be successful in providing value for the local community due to the country's vast resources in natural gas.[15,9]

The largest planned electricity project is the large-scale Grand Inga Dam Project, which, if completed, could single-handedly provide enough generation to meet 40 per cent of the continent's energy demand, making it the largest hydropower project in the world, with an estimated capacity of over 40,000 MW. One of the phases of the Grand Inga project, the Inga III dam, is currently underway and could provide 4.8 GW of capacity to the country. As the Inga III project advances, several other African countries have expressed interest in the project, with Eskom of South Africa and the Government of Angola signing agreements for the purchase of 2,500 MW and 5,000 MW of the project capacity, respectively.[9]

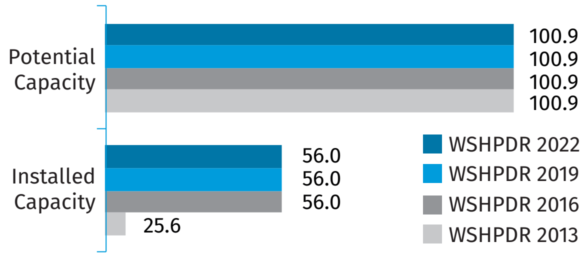
There are also projects that target other renewable energy sources such as the Kinshasa Solar City Project, which aims to build several solar power plants for a combined capacity of 1,000 MW. These energy projects contribute towards the country's goals of achieving universal electricity access by 2035 and reducing greenhouse gas emissions by 17 per cent by 2030.[9]

In the DRC, SNEL's tariffs are set by the Government and have not been revised since 2009 and are thus fixed at approximately 0.077 USD/KWh with variations based on inflation rather than changes in costs. Private operators fix their own tariffs in agreement with MEHR or relevant provincial authorities. Private operator Virunga SARL charges 0.21 USD/KWh (before taxes) in Goma and so does private operator SOCODEE for low-volume customers. For medium-volume customers, SOCODEE charges 0.16 USD/KWh. Private operator BBOXX charges between USD 17 and USD 100 per month for residential power service.[10]

SMALL HYDROPOWER SECTOR OVERVIEW

In the DRC, small hydropower (SHP) is defined as plants with an installed capacity of up to 10 MW. There was an estimated 56 MW of installed SHP capacity in 2017, which has not been updated as of the time of writing of this chapter. The total SHP potential identified has remained unchanged at approximately 101 MW since the previous edition of the *World Small Hydropower Development Report (WSHPDR 2019)* (Figure 4).[16]

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



Source: *WSHPDR 2019*,[16] *WSHPDR 2016*,[17] *WSHPDR 2013*[18]

There are five planned SHP projects in the DRC in Butembo, Kakobola, Beni, Lungudi and Masisi (Table 1) out of approximately 780 sites that were found to be suitable for SHP development.[14,9,20,21,22,23]

Table 1. **List of Selected Planned Small Hydropower Projects in the DRC**

Location	*Potential capacity (MW)*
Butembo	9.50
Kakobola	9.30
Beni	2.40
Lungudi	1.50
Masisi	0.22

Source: UNDP[19], AfDB[20], IJHD[21], Energy Capitol and Power[22], Hydro Review[23]

RENEWABLE ENERGY POLICY

The DRC does not have a comprehensive renewable energy policy framework. There is, as part of the National Strategic Development Plan 2019–2023 (NSDP), a highlighted need for the development of renewable energy sources, particularly the tremendous hydropower potential. This, however, is accompanied by an emphasis on the development and exploitation of natural gas.[24]

There are no specific government policies that target SHP development and no direct incentives for the development of SHP by the Government of the DRC. There are, however, donors and funding institutions interested in investing in the development of RE since the Government authorized a liberalization of the electricity sector. These include the World Bank, the African Development Bank (AfDB), the European Union and the United Kingdom Department for International Development (DFIF).[25]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

In the DRC, SHP plants are regulated by the same legislation as larger hydropower projects. The main legislation and regulation documents in the DRC concerning hydropower are:

- The 2014 Electricity Liberalization Law ref. 14/011;
- The Decree No. 18/054 of 2018 on the reduction of production and import/export costs of electricity;
- The Decree No. 18/053 of 2018 on setting the conditions for the import and export of energy to/from the DRC.[26]

COST OF SMALL HYDROPOWER DEVELOPMENT

In the DRC, the construction costs of SHP are site-specific. The main cost indicators are waterfall height and strength, with the cost falling as the height rises (Table 2). These costs are estimated based on previously built plants.[26]

Table 2. **Mean Costs of Small Hydropower Construction in the DRC**

Waterfall height	*Construction costs (USD/kW)*
High (> 200 m)	1,500–2,000
Medium (30–200 m)	2,000–4,000
Low (≤ 20 m)	4,000–6,000

Source: ANAPI[27]

BARRIERS AND ENABLERS TO SMALL HYDROPOWER DEVELOPMENT

The development of SHP in the DRC is mainly hampered by:

- Weakened institutional and regulatory framework: the decentralization law, the 2014 liberalization, the state disengagement law and the law on public utilities' transformation have not been effectively enforced due to lack of institutional support. This constitutes a discouraging factor for private parties interested in SHP;
- The centralized grid expansion in the country favours large and centralized generation assets to the detriment of smaller and localized generators such as SHP;
- High cost of initial capital and lack of affordable financial mechanisms discourage potential investors in the energy sector;
- Lack of institutional support for small-scale electricity projects;
- Lack of clear renewable energy policy in the country.

Enablers for SHP development in the DRC include:

- The 2014 liberalization law promises the decentralization of the electricity sector, thus inviting private actors and international investors to get involved in the sector. This would, if enforced, provide an enabling environment for the development of SHP;
- The abundant water resources in the country and the multiple identified potential sites for SHP.

REFERENCES

1. World Bank (2020). *Population, Total – Congo, Dem. Rep*. Available at https://data.worldbank.org/indicator/SP.POP.TOTL?locations=CD (Accessed 19 April 2022).
2. Encyclopædia Britannica (2022). *Democratic Republic of the Congo: Facts & Stats*. Available at https://www.britannica.com/facts/Democratic-Republic-of-the-Congo (Accessed 19 April 2022).
3. Cordell, D., Wiese, B., Lemarchand, R. & Payanzo, N. (2021). *Democratic Republic of the Congo*. Encyclopædia Britannica. Available at https://www.britannica.com/place/Democratic-Republic-of-the-Congo#ref40788 (Accessed 19 April 2022).
4. Climate Change Knowledge Portal (2020). *Country Summary – DRC*. Available at https://climateknowledgeportal.worldbank.org/country/congo-dem-rep#:~:text=The%20DRC%20has%20a%20largely,are%20generally%20cooler%20and%20drier (Accessed 19 April 2022).
5. Climate Change Knowledge Portal (2020). *Country – Congo, Dem. Rep*. Available at https://climateknowledgeportal.worldbank.org/country/congo-dem-rep/climate-data-historical (Accessed 19 April 2022).
6. Ministry of Environment and Sustainable Development (2021). *Revised Nationally Determined Contribution*. Available at https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Democratic%20Republic%20of%20the%20Congo%20First/CDN%20Revis%C3%A9e%20de%20la%20RDC.pdf (Accessed 19 April 2022).
7. United States Agency for International Development (USAID) (2021). *Democratic Republic of the Congo Water Resources Profile Overview*. Available at https://winrock.org/wp-content/uploads/2021/08/DRC_Country_Profile_Final.pdf (Accessed 19 April 2022).
8. International Renewable Energy Agency (IRENA) (2020). *Energy Profile – Democratic Republic of the Congo*. Available at https://www.irena.org/irenadocuments/statistical_profiles/africa/democratic%20republic%20of%20the%20congo_africa_re_sp.pdf (Accessed 20 April 2022).
9. Energy Capital and Power (2020). *DRC – Invest in the Energy Sector of the Democratic Republic of the Congo*. Available at https://energycapitalpower.com/report/drc-special-report-2020/ (Accessed 20 April 2022).
10. World Bank (2020). *Increasing access to electricity in the Democratic Republic of Congo. Opportunities and challenges*. Available at https://documents1.worldbank.org/curated/en/743721586836810203/pdf/Increasing-Access-to-Electricity-in-the-Democratic-Republic-of-Congo-Opportunities-and-Challenges.pdf (Accessed 20 April 2022).
11. United States Agency for International Development (USAID) (2017). *Conceptual Plan for Enhancing Transmission Infrastructure to Expand Electricity Access in the Democratic Republic of the Congo (DRC).* Available at https://pdf.usaid.gov/pdf_docs/PA00SX8K.pdf (Accessed 20 April 2022).
12. African Union – Programme for Infrastructure Development in Africa (AU-PIDA) (2019). *DRC - Angola Transmission Interconnector (DRC section*). Available at https://www.au-pida.org/view-project/393/ (Accessed 20 April 2022).
13. Smith, T. (2020). *Elsewedy Electric to build high voltage substation in DRC*. ESI Africa. Available at https://www.esi-africa.com/industry-sectors/transmission-and-distribution/elsewedy-electric-to-build-high-voltage-substation-in-drc/ (Accessed 20 April 2022).
14. National Agency for the Promotion of Investments (ANAPI) (2020). *Cahier Sectoriel - Investir dans le Sous-Secteur de l'Electricité.* Available at https://www.investindrc.cd/fr/IMG/pdf/cahier_sectoriel_electricite_octobre_2020_.pdf [in French] (Accessed 27 April 2022).
15. Africa News (2022). *In Rwanda, KivuWatt transforms gas from 'killer lake' into electricity*. Available at https://www.africanews.com/2022/01/20/in-rwanda-kivuwatt-transforms-gas-from-killer-lake-into-electricity// (Accessed 20 April 2022).
16. 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
17. 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.
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. United Nations Development Programme (UNDP) (2021). *Recrutement d'un cabinet chargé d'élaborer l'EIES du Projet de construction d'une microcentrale hydroélectrique (MCH) sur le site de Yame dans le territoire de Banalia, Province de TSHOPO*. UNDP Procurement Notices. Available at https://procurement-notices.undp.org/view_notice.cfm?notice_id=86577 [in French] (Accessed 21 April 2022).
20. Africa Development Bank (AfDB) (2021). *RDC - Projet des Centrales Hydroélectriques de l'Entité à Vocation Spéciale ENK dans la Province Nord Kivu en République Démocratique du Congo - SEFA Note de Synthèse de Projet*. Available at https://www.afdb.org/en/documents/rdc-projet-des-centrales-hydroelectriques-de-lentite-vocation-speciale-enk-dans-la-province-nord-kivu-en-republique-democratique-du-congo-sefa-note-de-synthese-de-projet [in French] (Accessed 21 April 2022).
21. International Journal on Hydropower and Dams (IJHD) (2020). *DRC seeks contractor to extend Lungudi hydroelectric plant*. Available at https://www.hydropower-dams.com/news/drc-seeks-contractor-to-extend-lungudi-hydroelectric-plant/ (Accessed 21 April 2022).

22. Energy Capital and Power (2020). *DRC's Kakobola Dam Community to Connect to Grid*. Available at https://energycapitalpower.com/drcs-kakobola-dam-community-to-connect-to-grid/ (Accessed 21 April 2022).
23. Ingram, E. (2021). *Brief: JLA Hydro Wins Contract for Wau Small Hydro Rehabilitation*. Hydro Review. Available at https://www.hydroreview.com/hydro-industry-news/brief-jla-hydro-wins-contract-for-wau-small-hydro-rehabilitation/#gref (Accessed 21 April 2022).
24. Government of the Democratic Republic of the Congo (2019). *Plan National Stratégique de Developpement 2019-2023*. Available at https://www.cd.undp.org/content/rdc/fr/home/library/plan-national-strategique-de-developpement.html [in French] (Accessed 22 April 2022).
25. French Embassy to the Democratic Republic of the Congo (2019). *Le Secteur de l'Electricite en Republique Democratique du Congo*. Available at https://www.tresor.economie.gouv.fr/PagesInternationales/Pages/13971f9d-3178-4715-bd09-5240a52d532b/files/176f8950-cd3c-481f-bc94-d18578236305 [in French] (Accessed 29 April 2022).
26. Electricity Sector Regulation Authority (ARE) (n.d.). *Lois et Décrets*. Available at https://are.gouv.cd/documentation/decrets/ [in French] (Accessed 22 April 2022).
27. National Agency for the Promotion of Investments (ANAPI) (2020). *Manuel de Montage des Projets des Microcentrales Hydroelectriques en R.D.Congo*. Available at https://www.investindrc.cd/fr/IMG/pdf/manuel_de_montage.pdf [in French] (Accessed 21 April 2022).

Equatorial Guinea

Annabel Johnstone, Kaboni

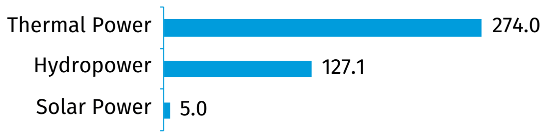
KEY FACTS

Population	1,432,744 (2021)[1]
Area	28,051 km^2 [2]
Topography	Located in Middle Africa, Equatorial Guinea has a mainland region and an insular region. The latter comprises the islands of Bioko, which hosts the country's capital of Malabo, and Annobón in the Gulf of Guinea. The mainland of Equatorial Guinea begins on a narrow coastal plain, lined with mangrove swamps. From there, the land rises into an elevated plateau of thickly forested hills to the border with Gabon, reaching (in a few places) upwards of 1,219 metres above sea level. The highest point of Equatorial Guinea is Pico Basile at 3,008 metres and is located on the island of Bioko, which is dominated by three extinct volcanoes. The lowest point of the country is the costal border with the Atlantic Ocean (0 metres above sea level).[2]
Climate	The climate is tropical, hot and humid all year round with no specific rainy season, though rainfall is heaviest in October. The temperatures are higher from January to May (average of 27 °C in the city of Bata on the mainland and an average of 26 ° C in Malabo) and lower from July to September, when they drop to approximately 21 °C in the higher altitudes of the mainland, whereas Malabo experiences relatively constant temperatures all year round.[3]
Climate Change	Climate change projections for Equatorial Guinea encompass increased temperatures (average increase of 3-3.5 °C from a range of predictions under an average global temperature rise of 4.9 °C) and rainfall. Rainfall is projected to increase by a median of 40 mm in October-December, representing an increase of approximately 20 per cent.[4,5]
Rain Pattern	Mean annual precipitation is 2,205 mm, although rainfall patterns vary dramatically between the islands and mainland Equatorial Guinea. On the island of Bioko, precipitation is below 2,000 mm per year in Malabo, while it exceeds 3,000 mm per year in the rest of the island. The dry season on the island of Bioko runs from December to February, although it is more pronounced in the northern part, where Malabo is located; the rainiest period is from May to October. The slopes of Pico Basile experience high rainfall, with the location influenced by the prevailing wind. On the mainland, known as Rio Muni, there are two peak rainfall periods: from March to May and from September to November. The rains are also quite abundant from December to February, especially along the coast, and the only moderately dry period is from June to August.[3,4]
Hydrology	Aside from the sections of the Atlantic Ocean, the dominant water body is the Mbini River (known as the Woleu River in Gabon), which runs generally from east to west through central Rio Muni. To the north, the Campo River (called the Ntem in French-speaking Africa) marks part of the frontier with Cameroon. The Utamboni River flows through the south. To the south-west lies the Muni, which is an estuary of various rivers of Gabon and southern Equatorial Guinea. To the east, the de-facto border with Gabon follows the meandering course of the Kié (or Kyé) River, rather than the legal frontier.[6]

ELECTRICITY SECTOR OVERVIEW

Equatorial Guinea had an installed capacity of 406.1 MW in 2019, of which 127.1 MW came from hydropower, primarily from the Djibloho plant (120 MW) (Figure 1). This is set to more than double, once the 200 MW Sendje hydropower project is completed.[7,10] The completion date is unknown, but expected soon following a recent investment of EUR 122 million (USD 148 million) into the project. There is also a solar-powered micro-grid with a 5 MW plant installed in 2017 in Annobon.[8]

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



Source: Wise Power Systems,[8] African Energy Portal[9]

In 2019, the majority of the total electricity generation of 478.8 GWh was produced by hydropower (447.7 GWh), with the installed capacity of non-renewable sources (274 MW) only producing 31.2 GWh (Figure 2).[9] Final consumption was 598 GWh in 2019, excluding electricity imports, which are not documented. The amount of solar power generation from micro-grids is unknown.

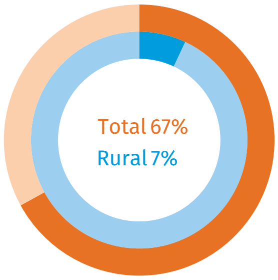
Figure 2. **Annual Electricity Generation by Source in Equatorial Guinea in 2019 (GWh)**

Source: African Energy Portal[9]

The state-owned electricity company Sociedad de Electricidad de Guinea Ecuatorial (SEGESA) under the Ministry of Mines and Hydrocarbons (MMIE) provides electricity under licensed monopoly and has several subsidiaries for generation, transmission and commercial operations. The SEGESA operates the country's two small electricity transmission networks, which comprise approximately 129 metres of high-voltage lines.[10] The network on the mainland serves the suburban area of Bata. The second distribution system, on Bioko, serves the capital Malabo and connects with the port of Luba. The electricity sector regulator is the Electricity Energy Regulatory Agency, while ownership of sectoral resources is left up to the national oil company GEPetrol. Equatorial Guinea is a member of the Central African Power Pool. Work on drilling three oil exploration wells in the Trident Energy-operated Block G oil production field commenced in 2021, and there are plans for the refurbishment and well intervention works across existing thermal plants.

In 2018, 67 per cent of the total population in the country had access to electricity: 90 per cent of urban residents and only 7 per cent of rural residents (Figure 3).[9]

Figure 3. **Electrification Rates in Equatorial Guinea in 2018 (%)**



Source: African Power Portal[9]

The Government of Equatorial Guinea is focusing on developing the fossil fuel industry within the country. In 2019, the Minister of Mines and Hydrocarbons (H.E Gabriel Mbaga Obiang Lima who is still in office at the time of writing) called for USD 1 billion of investment to develop 10 new fossil-based projects (of oil refineries and processing infrastructure). However, it is unclear whether suitable investment was raised for these projects.[12] The strategy to continue developing oil and gas resources in the country was repeated in discussions with the African Energy Chamber in 2020 as part of planning for recovery after the COVID-19 pandemic.[13]

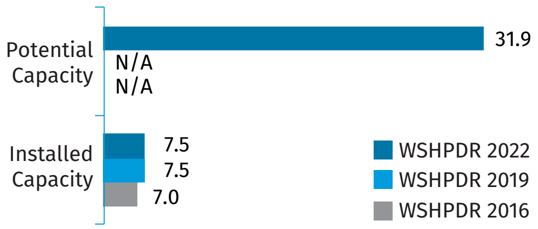
The Government of Equatorial Guinea has set electricity prices for enterprises and individuals in accordance with Law No. 3/2002. The electricity consumption price varies depending on the location and source of energy. Electricity consumers outside of Malabo and Bata are charged a fixed tariff per kWh. When the supplier is an independent producer, consumers are charged 0.099 USD/kWh. For independent diesel producers the price is 0.140 USD/kWh, while for independent hydropower producers the set price is 0.110 USD/kWh.[14]

SMALL HYDROPOWER SECTOR OVERVIEW

There is no official definition of small hydropower (SHP) in Equatorial Guinea. For this chapter, the definition of up to 10 MW will be used.

Although Equatorial Guinea is estimated to have 11–26 GW of hydropower potential, of which 50 per cent is deemed economically recoverable, SHP has received little attention in the country. Only three SHP plants were in use as of 2021.[11] In the south of Bioko, the old 3.8 MW hydropower plant in the town of Riaba has been operating at times at as low as 2 per cent of capacity due to lack of investment in maintenance and despite the increasing economic activity from the nearby freeport in Luba. The Riaba plant is to be refurbished and could see an increase in capacity to 6 MW, while the two micro-hydropower plants at Musola (0.4–0.5 MW) and Bikomo on the mainland (3.2 MW) are in need of upgrading.[11] Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed SHP capacity remained unchanged (Figure 4). The reason for the change in potential capacity since *WSHPDR 2019* is due to access to a new geo-spatial study released in 2018.[18]

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



Source: *WSHPDR 2013*,[15] *WSHPDR 2016*,[16] *WSHPDR 2019*,[17] Korkovelos et al.[18]

The Bikomo plant on the mainland (3.2 MW) was recently rehabilitated, as announced in a 2019 project review report.[19] Following the success of the Riaba and Musola plants, there were hopes for support for a 10 MW plant at Ilachi on Bioko island, as mentioned in a United Nations Development Programme (UNDP) project document.[19] Although details are not publicly available, a pre-feasibility study for the Ilachi location as well as water resource evaluations at sites in Belebu and Bococo Drumenwas were underway in 2019.[20]

Table 1. **List of Operational Small Hydropower Plants in Equatorial Guinea**

Name	*Location*	*Capacity (MW)*	*Launch year*
Musola I and II	Bioko	0.5	1942
Riaba	Bioko	3.8	1986
Bikomo	Rio Muni	3.2	–

Source: UNEP[11]

A geo-spatial analysis study conducted on GIS mapping software in 2018 identified 30 potential micro-hydropower sites (0.1–1.0 MW) totalling 10.9 MW and six SHP sites (1.01–10 MW) totalling 13.5 MW. The findings of the analysis suggest that there is at least 24.4 MW of undeveloped SHP potential in Equatorial Guinea. The exact locations, names and individual details of the sites are unknown, but the results from the geo-spatial mapping are visible in the study report.[18]

A separate study by Électricité du France (EDF) has identified 10 potential sites on Bioko Island at the six main rivers of the Cónsul, Balaopi/Tiburones, Musola, Tudela/Moaba, Ilachi, Ruma/Grande and Bao, though the individual capacities were not stated. The same study found that the most promising site for SHP development would be the Ilachi River with a height difference of 200 metres and a combined capacity of 12 MW in the dry season (and up to 18 MW in the rainy season).[11] The exact locations or names of these sites are not listed either and it is not known whether there is an overlap with the sites identified in the 2018 geo-spatial study. For this reason, the potential capacity estimate provided in this chapter is subject to error and potentially underestimated, due to possible overlap of data sources and lack of transparency.

Another project exploring SHP opportunities in Equatorial Guinea was conducted through the UNDP. The project aimed to complete a hydropower demonstration programme on the island of Bioko and to support the ongoing refurbishment of existing facilities at Riaba and Musola.[21] The project had a target of installing one SHP plant and as of 2019 this had not yet been achieved due to project delays.[19]

RENEWABLE ENERGY POLICY

Energy policy decision making in Equatorial Guinea primarily focuses on oil and gas developments, while in the power sector the focus is predominantly on larger-scale generation, grid extension and transmission concerns. Two main laws responsible for the energy sector are the Fundamental Law of 2012 and the Hydrocarbons Law No. 8/2006. As for the electricity sector, Decree 20/2005 allows for the transformation of the electricity sector.[14] Electricity tariffs were set by Decree No. 03/2002 of 21 May 2002.

Apart from the electrification plan, which was unveiled by the President in 2011, there is no longer-term renewable energy or off-grid electrification section or separate plan. There is a lack of procurement and licensing processes for independent power producers (IPPs), which creates only limited scope for renewable energy technology entrepreneurship and for IPPs in general.[14] There is no specific legislation relating to SHP and estimates of cost of SHP specific to the country are unavailable.

The European Union is a potential financing partner through the ACP-EU Energy Facility. The strong business relations between China and Equatorial Guinea may lead to additional development finance. Additionally, Spain and France continue to provide some project assistance.[21] The UNDP project on SHP mentioned above has been financed through the Global Environment Fund.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Equatorial Guinea is vulnerable to climate shocks and rainfall variability from climate change and measures are being taken within the country to address the risks, however, most are focused on forest conservation and weather analysis, rather than transitioning the energy system towards renewable electricity generation. These commitments are outlined in the country's National Adaptation Plan of Action (NAPA), which is overseen by the Ministry of Fisheries and Environment. However, within this plan, there is little mention of the energy system. There is also no large-scale international financial programme to specifically support these ambitions.[22]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Given the Government priority to develop oil and gas resources, it is not likely that Equatorial Guinea will become a priority location for SHP relative to other Middle-African countries, though there is a good availability of hydropower resources near large anchor loads (Bioko Island). Any SHP project in Equatorial Guinea will be entering an immature market and developers should expect the barriers that come with this, alongside a lack of institutional motivation for SHP.

Barriers to the development of the sector include:

- No consideration of innovative financing mechanisms for renewable energy developments (e.g., feed-in tariffs, carbon finance), nor regulation considering SHP development strategy;
- High upfront costs (augmented by custom duties) remain a factor further increasing the cost of introduction of renewable sources in a small market (no economy of scale);
- Policy objectives largely focus on expanding the oil and gas sector;
- Subsidized petrochemical products do not reflect the actual cost of fuel-generated electricity, distorting renewable generation as expensive;
- Data quality issues pertaining to the exact locations of the potential SHP sites identified.

Enabling factors include:

- Promising studies of viable sites for exploitation, particularly near the capital city on the island of Bioko;
- Interest in SHP from development institutions, such as the UNDP.

REFERENCES

1. World population review (2021). *Equatorial Guinea 2021.* Available at https://worldpopulationreview.com/countries/equatorial-guinea-population (Accessed 25 February 2021).
2. World Atlas (2020). *Maps of Equatorial Guinea.* Available at https://www.worldatlas.com/maps/equatorial-guinea (Accessed 25 February 2021).
3. Climatestotravel (2021). *Climates – Equatorial Guinea.* Available at https://www.climatestotravel.com/climate/equatorial-guinea (Accessed 25 February 2021).
4. World Bank Climate Change Portal (2021). *Equatorial Guinea, historical.* Available at https://climateknowledgeportal.worldbank.org/country/equatorial-guinea/climate-data-historical (Accessed 25 February 2021).
5. World Bank Climate Change Portal (2021). *Equatorial Guinea, projections.* Available at https://climateknowledgeportal.worldbank.org/country/equatorial-guinea/climate-data-projections (Accessed 25 February 2021).
6. Harrison-Church, R.J. & Pélissier, R. (2020). Encyclopaedia Britannica. *Equatorial Guinea*. Available at https://www.britannica.com/place/Equatorial-Guinea Accessed (Accessed 25 February 2021).
7. Afrik21 (2020). *Equatorial Guinea: BDEAC lends €122 million for Sendje hydropower plant.* Available at https://www.afrik21.africa/en/equatorial-guinea-bdeac-lends-e122-million-for-sendje-hydropower-plant/ (Accessed 29 April 2021).
8. Wise Power Systems (2017). *Wise Power Systems Installs 5 Megawatt Solar Micro Grid, Annobon Island, EG*. Available at http://wisepowersystems.com/wise-power-systems-installs-5-megawatt-solar-micro-grid-annobon-island-eg/#:~:text=Wise%20Power%20Systems%20has%20installed,10%20Megawatts%20of%20power%20storage (Accessed 29 April 2021).
9. African Energy Portal (AEP) (2021). *Equatorial Guinea*. Available at https://africa-energy-portal.org/country/equatorial-guinea (Accessed 25 February 2021).
10. REEEP (2013) *Equatorial Guinea (2012).* Available at https://www.reeep.org/equatorial-guinea-2012 (Accessed 14 May 2021).
11. United Nations Environmental Programme (UNEP) (2017). *Equatorial Guinea. Data acquired through the Renewable Opportunities Center (ROC) scheme at the end of 2015.* Available at https://wedocs.unep.org/bitstream/handle/20.500.11822/20489/Energy_profile_EquatorialGuinea.pdf?sequence=1&isAllowed=y (Accessed 29 April 2021).
12. Skedem (2019). *Equatorial Guinea courts $1bn to diversify energy sector*. Available at https://african.business/2019/12/economy/equatorial-guinea-courts-1bn-to-diversify-energy-sector/ (Accessed 2 April 2021).
13. African Energy Chamber (2020). *Equatorial Guinea hold discussions with African Energy Chamber on energy developments during Covid-19*. Available at https://energychamber.org/2020/08/03/equatorial-guinea-hold-discussions-with-african-energy-chamber-and-updates-on-energy-developments-during-covid-19/ (Accessed 2 April 2021).
14. UNEP (2016). *Equatorial Guinea*. Available at https://wedocs.unep.org/bitstream/handle/20.500.11822/20489/Energy_profile_EquatorialGuinea.pdf?sequence=1&amp per cent3BisAllowed= (Accessed 25 February 2021).
15. 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.
16. 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.
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. Korkovelos, A., Dimitrios, M., Siyal, S.H., Arderne, C., Rogner, H., Bazilian, M., Howells, M., Beck, H. & Roo, A.D. (2018). A Geospatial Assessment of Small-Scale Hydropower Potential in Sub-Saharan Africa. *Energies*. 11, 3100; doi:10.3390/en11113100.
19. Global Environment Facility (GEF) (2019). *Project Implementation Review (PIR): Promoting small scale hydropower in Bioko and other clean energy solutions for remote islands*. Available at https://undpgefpims.org/attachments/5143/213845/1729664/1744872/2019-GEF-PIR-PIMS5143-GEFID5286.docx (Accessed 29 April 2021).
20. Global Environment Facility (GEF) (2013). *Project Identification Form (PIF): Sustainable Energy for All: Promoting small scale hydropower in Bioko and other clean energy solutions for remote islands*. Available at https://publicpartnershipdata.azureedge.net/gef/PMISGEFDocuments/Climate%20Change/Equatorial%20Guinea%20-%20(5286)%20-%20Sustainable%20Energy%20for%20All-%20Promoting%20Small%20Scale/PIMS%205143%20EqGuinea%20GEF5%20PIF%2015-Mar-2013%20Resubmission.docx (Accessed 29 April 2021).
21. United Nations Development Programme (UNDP) (n.d.). *Project Document - Project title: Sustainable Energy for All: Promoting small-scale hydropower in Bioko and other clean energy solutions for remote islands*. Available at https://info.undp.org/docs/pdc/Documents/GNQ/PIMS%205143%20EqGuinea%20SE4ALL%20-%20PRODOC%20Final%2009032016_doc%20final.pdf (Accessed 14 May 2021).
22. United Nations Convention on Climate Change (UNFCCC) (2015). *Republica de Equatorial Guinea INDC.* Available at *https*://www4.unfccc.int/sites/submissions/indc/Submission per cent20Pages/submissions.aspx (Accessed 25 February 2021).

Gabon

Annabel Johnstone, Kaboni

KEY FACTS

Population	2,172,579 (2019)[1]
Area	267,667 km^2 [2]
Topography	Gabon is divided into three distinct regions: a narrow coastal plain to the west, a hilly mountainous interior and a savanna in the far east and south. Rainforest covers nearly 85 per cent of the country's territory.[2] Significant mountains include the Cristal Mountains in the north-east and the central Chaillu Massif formed of granite, saddled by the Ogooué River, which carves through limestone. The highest peak in Gabon is Mount Bengoué, in the Crystal Mountains at an elevation of 1,070 metres. The highest peak in the Chaillu Mountains is Mount Milondo, at an elevation of 1,020 metres. The country also has hundreds of caves located in the dolomite and limestone rock formations in the central and eastern areas.[3]
Climate	Located on the Equator, Gabon has a hot and humid climate all year round in the north and in inland areas, with a short dry season from June to August. Average temperatures year-round range between 25 °C and 27 °C in coastal lowlands and between 22 °C and 25 °C inland. The country has experienced some of its highest temperatures along the coast and in the capital city of Libreville.[3]
Climate Change	Gabon has experienced a general warming trend with the mean annual temperature having increased by 0.6 °C since 1960. The number of hot days in the country is projected to increase by 25-75 per cent annually by 2060. Annual mean temperatures will increase by 1.8 °C by 2040-2059, according to the worst-case emissions scenario of up to 5.4 °C by 2100. Climate projections indicate that warming will occur across the country, with faster rates in the inland areas and slower rates in the coastal regions.[4,5]
Rain Pattern	Gabon receives an abundance of rainfall, typically ranging from 1,500 mm to 3,500 mm per year. The wet season lasts from October to May, with a mean monthly rainfall of 200–250 mm and peak average rainfall in October–November at 280 mm/month. However, mean annual rainfall in Gabon has dropped at an average rate of 3.8 mm monthly (approximately 2.6 per cent) per decade since 1960. The coastal areas of Gabon are expected to experience an increase in precipitation, while the inland areas may experience decreased precipitation. Country average precipitation is expected to experience a slight overall increase of 33.8 mm by 2040–2059, under a multi-model ensemble analysis of worst-case scenarios (RCP8). At the same time, rainfall variability is expected to increase with greater intensity and frequency of heavy rainfall.[4,5]
Hydrology	Gabon has substantial renewable water resources, with 166x10^9 m^3 per year, of which 98 per cent is produced internally and found as surface water (with a 36 per cent overlap with groundwater sources). The majority of the surface water is carried by the major river, the Ogooué (also spelt Ogowe), which is 1,200 km long and has several tributaries. Flowing through Gabon for almost its entire course, the river's drainage area extends for almost 222,700 km^2, within Gabon and also neighbouring Congo and Cameroon. The river originates in the north-east in Congo, and travels through the main watersheds of the Chaillu Massif and the Crystal Mountains, and empties into the Atlantic Ocean.[6,7]

ELECTRICITY SECTOR OVERVIEW

In 2019, Gabon had a total installed capacity of 632.3 MW, of which 334.3 MW came from renewable sources. The dominant renewable energy source in the mix is hydropower, accounting for 332.0 MW of installed capacity, with the remainder split between solar power (1.4 MW) and bioenergy (1.2 MW) (Figure 1).[8]

Net production plus imports of electricity in Gabon reached 2,331.5 GWh in 2018, compared to 2,327.1 GWh in 2017. In 2018, hydropower was the source of 980.9 GWh, a rise of over 7 per cent in just one year (913.6 GWh in 2017). Thermal generation stood at 839.8 GWh in 2018, down from 967.5 GWh in 2017.[10] Solar power and bioenergy generation were estimated at 2.1 GWh and 14.1 GWh, respectively, in 2018.[8] Thus, total electricity generation in the country in 2018 amounted to 1,836.9 GWh (Figure 2).[8,10] Gabon does not export electricity and is a net-importing country. Imports of electricity have been steadily increasing since 2013 and reached 445.6 GWh in 2019, demonstrating an increase of nearly 11 per cent compared to 2018.[8]

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

Source: African Energy Portal,[8] Oxford Business Group[9]

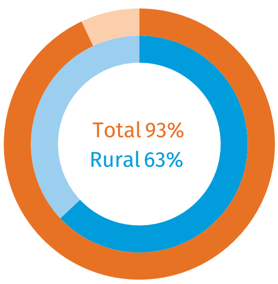
Note: This is an indicative estimate based on an average from several sources.

Figure 2. **Annual Electricity Generation by Source in Gabon in 2018 (GWh)**

Source: African Energy Portal,[8] SEEG[10]

Access to electricity across the population is at 93 per cent nationally, with 97 per cent in urban areas and 63 per cent in rural areas (Figure 3).[8] Increased household demand (15–20 per cent increase on a yearly basis in Libreville alone) is placing a strain on grid balancing. The Libreville grid — one of five isolated distribution areas in the country — is experiencing these pressures on the grid most strongly and load shedding still occurs in certain neighbourhoods. The lack of a national transmission grid has contributed to a tight supply-demand margin in a large number of the country's urban areas.[10]

Figure 3. **Electrification Rates in Gabon in 2018 (%)**



Source: Africa Energy Portal[8]

The Ministry of Mines, Petroleum and Hydrocarbons and the Ministry of Energy and Hydraulic Resources have joint responsibility for the energy sector. The Société d'Energie et d'Eau du Gabon (SEEG) is the sole generator, transmitter and distributor of electric energy in the country. SEEG is vertically integrated and holds a 20-year lease to the monopoly, which was renewed in 2017. Gabon is a member of the Central African Power Pool (CAPP).

The electricity sector is regulated by the Water and Energy Sector Regulatory Agency. The electricity tariff is capped at 0.23 USD/kWh for low-voltage single-phase power and declines to 0.09 USD/kWh based on usage (0.23 USD/kWh for 12 kW, 0.09 USD/kWh for 1 kW). For three-phase electricity, the tariff is calculated based on the time of use: for long use (over 2,880 hours), general use (1,441–2,880 hours) and short use (less than 1,441 hours) the tariffs are 0.13 USD/kWh, 0.15 USD/kWh and 0.16 USD/kWh, respectively.[11]

The electricity sector of Gabon and indeed its entire economy is currently heavily dependent on the large oil resources available within the country. Gabon is the fourth largest oil producer in Africa, and is considered to be in the top five richest African countries in terms of raw natural resources. The country has had plans to diversify the energy sector and remove oil dependence since 2010, as outlined in the Emerging Gabon Strategic Plan. The commitment to this objective was renewed in 2020 after the country was heavily affected by the oil price crash during the COVID-19 pandemic. With most of the population concentrated in the capital of Libreville and the rural population scattered in difficult to access areas, the current objectives are to enhance service to those connected, lower service prices and ensure access in rural communities.[12,13]

Since 2016 there have been four thermal plants in the country: two in Libreville, including a 128 MW plant in Owendo run by SEEG and a 70 MW plant in Alé nakiri run by the Social Democratic Party (SDP); and two in Port-Gentil, including a 48 MW plant operated by SEEG and a 52 MW plant run by the SDP, which is to be connected to the grid shortly. In addition to the SDP-owned 160 MW Grand Poubara hydropower plant that powers Franceville, Gabon has three major hydropower plants operated by SEEG. The Kinguélé plant has a capacity of 59 MW and is located roughly 200 km east of Libreville along the Mbei River, supplying Libreville via a 224 kV line. The second hydropower plant, Tchimbélé, is located along the same river and has a capacity of approximately 69 MW, while the third plant, Petit Poubara, near Franceville, has a capacity of 38 MW. The Grand Poubara and Alénakiri plants belonging to the SDP are operated under concession by China-based Sinohydro and Israel-based Telemenia.[14]

Several large hydropower projects are in development: the 85 MW Ngoulmendjim plant (550 GWh of annual generation) and the 15 MW Dibwangui plant (90 GWh) backed by the Gabonese Fund for Strategic Investments (FGIS) and Eranove; and the 35 MW Kinguélé-Aval plant (204 GWh) backed by FGIS and Meridiam. Furthermore, detailed preliminary studies of the Booué project on the Ogooué River (412 MW, 2,950 GWh) and the Tsengué-Lélédi project on the Ivindo River (300 MW, 1,286 GWh) have been initiated by the African Development Bank (AfDB) on behalf of the Economic Community of Central African States (EEECAS).[15] Gabon is examining financing options for two further hydropower projects: FE2 (36 MW, 240 GWh) and Empress Falls (88 MW, 500 GWh).[16]

In October 2019, French fund manager Meridiam signed a 33-year concession contract with the Government of Gabon to construct a 34 MW hydropower plant on the Mbei River, 100 km from Libreville. Construction was delayed due to the outbreak of COVID-19 and new projections state that the project will be completed in 2023.[17]

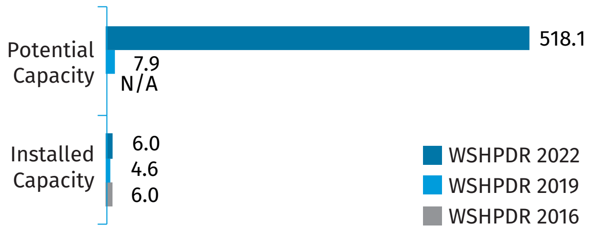
SMALL HYDROPOWER SECTOR OVERVIEW

There is no official definition of small hydropower (SHP) in Gabon. This chapter will use to the up to 10 MW definition of SHP. The hydropower sector in Gabon is heavily dominated by large-scale hydropower, and the country has significant hydropower potential of which an estimated 6,000 MW remains undeveloped.[18] Gabon has ambitions to become a net exporter of electricity in 2030, thus, the development of SHP to support internal electricity demand has viability.

There are three SHP plants in Gabon with a total installed capacity of 6 MW (Table 1).[19] There have not been any developments in the country's SHP sector since the publication of the *World Small Hydropower Development Report* (*WSHPDR) 2019*. However, SEEG launched a project worth USD 12.7 million for the rehabilitation of the Bongolo SHP plant, which operated at half (approximately 2.5 MW) of its installed capacity after 2010.[20] The change in installed SHP capacity since the *WSHPDR 2019* is a result of this rehabilitation work, and the change in potential capacity is due to access to new information from a geospatial feasibility study (Figure 4).

A geospatial assessment of SHP potential in Sub-Saharan Africa in 2018 found several opportunities to exploit mini- and small-scale hydropower in Gabon. The study found 105.9 MW of potential capacity at 343 sites with mini-hydropower potential (0.1–1 MW) and 412.1 MW of potential capacity available from 129 SHP sites (1–10 MW), resulting in a total of 518.1 MW of technical SHP potential. Though the locations and names of these sites are unknown, the mapped results from the geo-spatial analysis are visible in the study.[19]

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



Source: Korkovelos et al. 2018,[19] *WSHPDR 2016*,[21] *WSHPDR 2019*[22]

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

Name	*Capacity (MW)*	*Launch year*
Bongolo	5.46	1992
Mbigou	0.38	1996
Medounneu	0.20	1994

Source: Agence Cofin,[23] SEEG[24]

RENEWABLE ENERGY POLICY

In July 2020, Gabon laid out its ambitions to become an emerging economy in the region by financing a rapid and sustainable transition from a "brown" to a "green" economy. The Strategic Plan for Gabon's Emergence (PGSE) is supported by a number of international organizations and coordinated by the joint Sustainable Development Goals (SDG) fund (alongside a commitment of USD 1 million) to accelerate a transition away from an extractive and oil-based economy to a green and sustainable one. The PGSE was born out of the commitment of Gabon to lower its greenhouse gas (GHG) emissions in 2017 and bolstered by the large economic shock of the oil-price crash in 2020, incentivizing the country's transition away from unsustainable markets. The planned transition will open up the market for SHP in the coming years and place renewable energy developers as valuable partners to the Government of Gabon. The joint project's approach aims to:

- Build an Integrated National Financing Framework (INFF) for both the PGSE, the SDGs and the transition to a green economy;
- Prepare the ground, through study and market assessment, for expanded use of innovative green financing mechanisms to power the country's sustainable development;
- Rationalize the development financing ecosystem in Gabon;
- Develop national capacities in the mastery of SDG financing instruments to accelerate the achievement of SDGs related to climate change at the global level; and
- Establish an effective and inclusive system for monitoring public resources allocated to the transition to a green economy, aiming at creating a nation-wide SDG financing dialogue mechanism.[25]

Hydropower plays an important role in this transition through the creation of jobs, capacity building and enabling mitigation of the nation's dependency on oil and gas as the primary energy sources. Thus, promotion of hydropower is seen as one of the four pillars of green transformation acceleration alongside the creation of green jobs, promotion of green entrepreneurship for youth and women and sustainable cities.[26]

In light of the recent PGSE, it is highly likely that the regulations regarding renewable power generation will change imminently to the benefit of both utility scale and SHP developers through simplified and accelerated licence pathways and an increase in financial mechanisms to advance investment. This is especially the case as the PGSE represents the first targeted, holistic policy development for renewable sources in Gabon.[16] As reported by the Director General of the Ministry of Energy and Hydraulic Resources, a key change in the licensing process for hydropower will be a move from the outdated least-cost, project-by-project approach to a licensing procedure inviting multiple stakeholders to perform exploitation of all available sites in a river basin — a system-scale approach.[27] It is important to note also that due to the joint SDG approach, environmental standards and ecosystem services are seen as highly valuable and so any prospective projects are likely to require a detailed Environmental and Social Impact Assessment (ESIA) and environmental risk mitigation reports.

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

The above mentioned PGSE should inject much needed innovation into finance mechanisms for SHP and general private investments in the hydropower sector of Gabon. Planned or existing projects may also be financed through national or international institutions. The AfDB-financed Fund for Development and Expansion and the European Fund (FODEX) provide financing to small and medium-sized companies.

The Overseas Private Investment Corporation (OPIC), a United States Government agency, offers project financing in Gabon. There is also scope for finance from Gabon Special Economic Zone (GSEZ), which was started in 2010 as a joint venture between Olam International Ltd., the Government of Gabon and Africa Finance Corporation with a mandate to develop infrastructure, enhance industrial competitiveness and build a business-friendly ecosystem in Gabon.[28]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Climate predictions see an increase in rainfall in Gabon in all scenarios, so it is likely that the country will have increased total discharge.[4] This would require special consideration of construction materials and design, as landslides would be more likely.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Though attention will undoubtedly be focused on large hydropower projects due to the large natural resource base of Gabon, there is considerable scope for SHP development, especially in rural energy access schemes where export scale evacuation lines are less viable due to primary forest. More information is needed on the regulation changes coming through with respect to licensing procedures based on catchment basins rather than site-by-site licensing. For SHP, it would be beneficial to partner with large hydropower developers, to exploit this regulation change efficiently. Overall, Gabon looks promising for SHP development, keeping the below barriers and enablers in mind.

The key barriers to SHP development include:

- Legal framework and regulations are likely to change imminently due to the development of the PGSE;
- Lack of local expertise;
- Inadequate energy, water and transportation infrastructure;
- High levels of bureaucracy;
- Poor quality of state services;
- Relatively high labour costs.[20,25,26]

The key enablers include:

- The strategic plan of Gabon to transition from a “brown” to “green” economy opens huge potential for hydropower development;
- The Doing Business score of Gabon (45) has been steadily improving, with considerable improvement in ease of setting up a business.[29]

REFERENCES

1. World Bank (2019). *Gabon, data.* Available at https://data.worldbank.org/country/gabon (Accessed 25 February 2021).
2. World Atlas (2020). *Maps of Gabon*. Available at https://www.worldatlas.com/maps/gabon (Accessed 25 February 2021).
3. Climatestotravel (2021). *Climate – Gabon.* Available at https://www.climatestotravel.com/climate/gabon (Accessed 25 February 2021).
4. World Bank Climate Change Knowledge Portal (2021). *Gabon, historical.* Available at https://climateknowledgeportal.worldbank.org/country/gabon/climate-data-historical (Accessed 25 February 2021).
5. World Bank Climate Change Knowledge Portal (2021). *Gabon, projections*. Available at https://climateknowledgeportal.worldbank.org/country/gabon/climate-data-projections. (Accessed 25 February 2021).
6. Food and Agriculture Organization of the United Nations (FAO) (2017). *Profil du pays - Gabon.* Available at http://www.fao.org/aquastat/fr/countries-and-basins/country-profiles/country/GAB (Accessed 25 February 2021).
7. Encyclopaedia Britannica (2021). *Ogooué River.* Available at https://www.britannica.com/place/Ogooue-River (Accessed 25 February 2021).
8. African Energy Portal (2020). *Gabon*. Available at https://africa-energy-portal.org/country/gabon (Accessed 25 February 2021).
9. Oxford Business Group (n.d.). *Gabon developing more hydropower and natural gas resources* Available at https://oxfordbusinessgroup.com/overview/expanded-offerings-due-continuation-low-global-oil-prices-gabon-developing-its-hydropower-and (Accessed 14 May 2021).
10. Societe d’Energie et d’Eau du Gabon (SEEG) (2018). *Rapport Annuel*. Available at https://www.seeg-gabon.com/med/pub/Rapport_Activite_2018_1582281851397.pdf (Accessed 02 April 2021).
11. Societe d’Energie et d’Eau du Gabon (SEEG) (2018). *Tarifs des fournitures d’electricite BT et d’eau applicables sur l’ensemble du Gabon.* Available at https://www.seeg-gabon.com/med/trf/Presentation_des_tarifs_1542815352496.pdf (Accessed 02 April 2021).
12. Energypedia (2019). *Gabon Energy Situations.* Available at https://energypedia.info/wiki/Gabon_Energy_Situation (Accessed 25 February 2021).
13. Power Africa (2016). *Gabon Fact Sheet*. Available at

https://2012-2017.usaid.gov/powerafrica/gabon (Accessed 25 February 2021).
14. Oxford Business Group (2021). *Gabon developing more hydropower and natural gas resources.* Available at https://oxfordbusinessgroup.com/overview/expanded-offerings-due-continuation-low-global-oil-prices-gabon-developing-its-hydropower-and (Accessed 25 February 2021).
15. US Energy Information Administration (2020). *Gabon: Analysis*. Available at https://www.eia.gov/international/analysis/country/GAB (Accessed 25 February 2021).
16. Construction Review Online (2019). *Construction of hydroelectric power stations in Gabon to begin. Available at* https://constructionreviewonline.com/news/construction-hydroelectric-power-stations-gabon-begin/ (Accessed 25 February 2021).
17. Ngari, A. (2020). *Tackling Gabon's future energy needs scientifically.* Available at https://www.esi-africa.com/industry-sectors/generation/tackling-gabons-future-energy-needs-scientifically/ (Accessed 25 February 2021).
18. REEEP (2012). *Gabon.* Available at https://www.reeep.org/gabon-2012 (Accessed 02 April 2021).
19. Korkovelos, A., Dimitrios, M., Siyal, S.H., Arderne, C., Rogner, H., Bazilian, M., Howells, M., Beck, H. & Roo, A.D. (2018). A Geospatial Assessment of Small-Scale Hydropower Potential in Sub-Saharan Africa. *Energies*. 11, 3100. doi:10.3390/en11113100.
20. Construction Review Online (2020). *Gabon starts rehabilitating the Bongolo hydroelectric power station* https://constructionreviewonline.com/news/gabon-starts-rehabilitating-the-bongolo-hydroelectric-power-station/ (Accessed 14 May 2021).
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. Agence Cofin (2020). *Gabon: la SEEG consacre 12,7 millions $ à la réhabilitation du barrage de Bongolo (5 MW).* Available at https://www.agenceecofin.com/hydroelectricite/0911-82216-gabon-la-seeg-consacre-12-7-millions-a-la-rehabilitation-du-barrage-de-bongolo-5-mw (Accessed 2 May 2021).
24. Societe d'Energie et d'Eau du Gabon (SEEG) (2016). *Rapport Annuel.* Available at http://arsee-gabon.com/fr/rapport-annuel-arsee-2016-telecharger/ (Accessed 14 May 2021).
25. Joint SDG Fund (2021). *Gabon and the SDGs "Beyond Oil": Financing a Rapid and Sustainable Transition from a "Brown" to a "Green" Economy* Available at https://www.jointsdgfund.org/programme/gabon-and-sdgs-beyond-oil-financing-rapid-and-sustainable-transition-brown-green-economy (Accessed 25 February 2021).
26. Joint SDG Fund (2020). *Joint Programme Document (ProDoc_Gabon.pdf)*. Available at http://mptf.undp.org/factsheet/project/00122134 (Accessed 25 February 2021).
27. Department of Commerce USA (2021). *Gabon: Project financing.* Available at https://www.privacyshield.gov/article?id=Gabon-Project-Financing (Accessed 25 February 2021).
28. Gabon Special Economic Zone (GSEZ) (2018). *About GSEZ.* Available at https://gsez.com/about-gsez.php (Accessed 25 February 2021).
29. The World Bank (2019). *Ease of doing business in Gabon.* Available at https://www.doingbusiness.org/en/data/exploreeconomies/gabon/employing-workers (Accessed 25 February 2021).

Sao Tome and Principe

International Center on Small Hydropower (ICSHP)

KEY FACTS

Population	219,161 (2020)[1]
Area	1,001 km[2] [2]
Topography	Sao Tome and Principe is an archipelago consisting of two small islands and some islets located in the Gulf of Guinea, approximately 300 kilometres west of the African coast. The Islands are of volcanic origin and the terrains are predominately rugged with steep slopes, particularly in the western and southern regions on both islands. While volcanoes are present, neither island has experienced volcanic activity in recent centuries. The highest point is Pico de Sao Tome, at 2,024 metres, and is located in the western part of Sao Tome Island. The highest point on Pricipe Island is Pico de Principe at 948 metres, located in the southern region. Both islands have small coastal plain regions situated in the north-east.[2]
Climate	The islands have a tropical, maritime climate with little variation of temperature in a given region throughout the year. Temperatures in lower elevations and coastal regions are consistently in the upper 20s °C, while temperatures in higher elevations may drop to approximately 10 °C at night. Seasons are determined by rainfall with a dry season between June and August and a wet season between September and May.[2,3]
Climate Change	As islands, some of the most pressing concerns of climate change in Sao Tome and Principe are rising sea levels, coastal flooding and coastal erosion. These phenomena have been experienced already and are expected to intensify in the upcoming decades. Additionally, there have been noticeable elongated dry seasons, causing droughts, while prevalence of excessively heavy rainfalls and storms is increasing during the wet season, causing floods and landslides.[3]
Rain Pattern	Precipitation largely occurs during the wet season between September and May throughout the country, although average amounts vary by region, gradually decreasing from south-west to north-east. Average annual rainfall in the southern and western mountainous regions of both islands is above 5,000 mm and can exceed 7,000 mm in some areas. In the far north-eastern regions, annual rainfall is the lowest, approximately 760 mm.[2]
Hydrology	Within the mountainous terrain are many swift flowing rivers beginning in the country's interior highlands and flowing downwards to the coasts. The largest river is the Io Grande on Sao Tome draining in the south-east. Other important rivers on Sao Tome include the Abade, Manuel Jorge and Rio d'Ouro. The largest and most important river on Principe Island is Rio Papagaio. Many rivers have seasonal flows and weaken during the country's dry season.[4]

ELECTRICITY SECTOR OVERVIEW

In 2020, total installed capacity in Sao Tome and Principe was 38.6 MW, although total available capacity was considerably lower. On the country's grid, thermal power, largely diesel fuel, amounted to 35.68 MW (95 per cent) and hydropower to 1.92 MW (5 per cent) (Figure 1). Additionally, there were some other isolated systems in remote areas not connected to the grid amounting to approximately 1 MW. There are a total of 7 power plants in operation in the country, 6 of which are thermal power and 1 hydropower. None of the power plants operated with their full installed capacity in 2020, leaving a total available capacity of 22.15 MW (Table 1).[5]

Figure 1. **Installed Electricity Capacity by Source in Sao Tome and Principe in 2020 (MW)**

Source: EMAE[5]

Table 1. **Installed and Available Capacity in Sao Tome and Principe**

	Installed capacity (MW)	*Available capacity (MW)*
Sao Tome	34.80	20.31
Principe	2.80	1.24
Off-grid	1.04	0.60
Total	**38.64**	**22.15**

Source: EMAE[6]

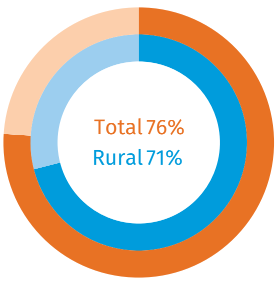
In 2020, total electricity generation was 109.6 GWh. Thermal power generated 104.7 GWh (95 per cent) and hydropower generated 4.9 GWh (5 per cent) (Figure 2). Net generation after energy used by power plants was 103 GWh. Due to significant inefficiencies, the electricity sector has experienced large annual losses in recent years and in 2020, losses represented 33.1 GWh, or over 32 per cent. After losses, the actual total electricity consumed in the country was 69.9 GWh for the year.[5]

Figure 2. **Annual Electricity Generation by Source in Sao Tome and Principe in 2020 (GWh)**

Source: EMAE[5]

The overall electrification rate in 2020 was 76 per cent, including over 78 per cent in urban areas and 71 per cent in rural areas.[6] Most of the electricity consumption in the country is concentrated in the capital city and surrounding areas. In 2020, there were 50,402 electricity customers that consumed a total of 69.9 GWh. The 42,489 residential customers represented 84 per cent of total customers and consumed 49 per cent of the electricity. Government and state institutions consumed 16 per cent of the total, commercial customers 13 per cent, industrial customers 8 per cent and the remaining 14 per cent was distributed amongst other types of customers.[5]

Figure 3. **Electrification rate in Sao Tome and Principe in 2020 (%)**



Source: World Bank[6]

In 2014 the electricity sector was restructured under Legal Framework of the Electricity Sector (RJSE) Decree-Law No. 26/2014. This decree essentially liberalized the market for private entities to invest in electricity production, however, there is a lack of clear regulation. As of 2020, the Government was working with external partners such as the United Nations Development Programme (UNDP) to create complimentary legislation that would further outline the standards for a liberalized market. Currently, the main electricity company is the Water and Electricity Company (EMAE), which is 51 per cent owned by the state and 49 per cent owned by private companies. EMAE is responsible for all the electricity production, distribution and transmission in the country. The distribution and transmission networks use a combination of underground and overhead medium- and low-voltage lines from 0.4 kV to 30 kV.[7]

With the support of international donors, the Government has made efforts to improve and extend the transmission and distribution network, construct new substations, transformation posts and a new national dispatch centre based on smart technologies and train technicians in order to adapt to the new quantitative and qualitative technological requirements of the public electricity service. In 2016 and 2017, transmission and distribution lines were rehabilitated and extended to the north and north-east to Santa Catarina Island and to the south of the island of Sao Tome as far as Sao Joao dos Angolares, as well as to Monta Alegre and Praia Burra in the island of Principe.[8]

Expansion of electricity access and reliability is incorporated into many of the recent national plans. The Sao Tome and Principe 2030 Transformation Agenda set out the Government's goals to pursue sustainable development, provide access to energy as an essential public good to the entire population, preserve the environment by designing projects that minimize negative environmental impacts and creating favourable conditions for the implementation of relevant environmentally friendly solutions and promote public-private partnerships with companies that have financial capital, technologies and human resources in the field of renewable energy.[7] The National Development Plan of 2017–2021 also highlighted the need to extend electricity access to the whole population as well as the need to rehabilitate the distribution and transmission infrastructure to avoid losses and increase energy efficiency, to increase electricity production through encouraging public-private partnerships and investments and to ensure a 50 per cent share of renewable energy sources on the grid by 2030. Additionally, the World Bank provided support to the Ministry of Infrastructure and Natural Resources with the preparation of a Least Cost Development Plan in 2018, which set out a roadmap to attain the necessary new generation capacities with the lowest cost investments.[7]

Electricity tariffs are set by EMAE and are approved by the General Regulatory Authority (AGER). Tariffs vary depending on the category and volume of consumption and are not differentiated by region due to the uneven distribution of the population across the country (Table 2).

Table 2. **Electricity Tariffs in Sao Tome and Principe**

Type of consumer	*Tariffs (STD/kWh (USD/kWh))*
Domestic:	
< 100 kWh	1.67 (0.07)
100–300 kWh	2.45 (0.11)
> 300 kWh	3.84 (0.17)
Commercial	3.84 (0.17)
Government, state institutions	6.03 (0.26)
Embassies, international institutions, other	7.03 (0.30)

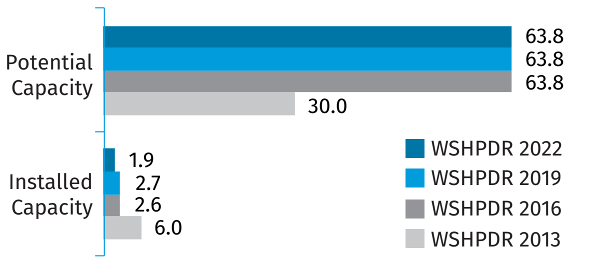
Source: EMAE[8]

SMALL HYDROPOWER SECTOR OVERVIEW

Small hydropower (SHP) is defined as power plants up to 10 MW, with a further breakdown into mini-hydropower (101 kW–1 MW) and micro-hydropower (1–100 kW). For the purposes of this chapter, all hydropower plants up to 10 MW will be considered SHP.

In 2020, the installed capacity of SHP in Sao Tome and Principe was 1.92 MW.[5] According to a study carried out in 2008 by CECI Engineering Consultants, Inc., there is a total potential capacity of 63.8 MW, indicating that just 3 per cent of the potential capacity is currently in operation.[7] Compared to the results of the *World Small Hydropower Development Report (WSHPDR) 2019*, potential capacity has remained the same and installed capacity has decreased due to removing plants not in operation for several years from the value of installed capacity (Figure 4).

Figure 4. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in Sao Tome and Principe (MW)**



Source: EMAE,[5] ALER,[7] *WSHPDR 2019*,[9] *WSHPDR 2016*,[10] *WSHPDR 2013*[11]

Historically, there have been four SHP plants in the country, although only one has been in operation in the past decade. The Contador plant, located in the north-western region on Sao Tome Island, has been in operation for over 50 years and is in need of refurbishment. The installed capacity is 1.92 MW but the current available capacity is approximately 1.8 MW. As of 2020, a rehabilitation project on the Contador plant has been approved with financial support of the World Bank with aims to increase the installed capacity to up to 4 MW. The budget for this project will be USD 39 million.[7]

The three old SHP plants that are now no longer in use are the Guégué, Agostinho Neto and Papagaio. The Guégué was constructed in 1941 with a capacity of 320 kW and closed in 2011. While some infrastructure is still at the site, the turbine and electrical system have been fully removed. In 2019, private company STP Urbano made an agreement to rebuild an SHP plant at that location. The company plans to demolish most of the remaining infrastructure and build a plant with a capacity of 1 MW. The commencement on construction of this project has not yet been announced.

The Agostinho Neto plant was constructed during colonial times and later modernized with a capacity of 344 kW. Due to electromechanical problems, the plant was dismantled in 2007 and has been inoperable since. STP Urbano has also shown interest in demolishing and rebuilding the plant, but no concrete purchase has been made. The Papagaio plant was the only hydropower plant to exist on Principe Island. It was constructed in 1993, first with an oversize 400 kW turbine but after two weeks changed for an 80 kW turbine that was in operation for just a few weeks before the transformer was brought to be installed at a nearby thermal power plant instead. In June 2020, a call for proposals to carry out a feasibility study on the project was launched, with no further updates since.[7]

The 2008 study of SHP potential in Sao Tome and Principe identified 34 sites with a combined potential capacity of 63 MW and estimated annual production of 244 GWh (Table 3).[7] The large majority of the sites are located on Sao Tome Island, while three of them are on Principe Island. Development of these sites would more than double total installed capacity and electricity generation for the country, as well as provide access to electricity in nearby remote communities.

Table 3. **List of Selected Potential Small Hydropower Projects in Sao Tome and Principe**

Name	*Location*	*Potential capacity (MW)*
Dona Eugénia	Io Grande River	9.6
Monte Rosa	Quija River	3.75
Bombaim	Abade River	3.5
Santa Irene	Lemba River	3.0
Claudino Faro	Abade River	2.0
Mato Cana	Abade River	2.0
Neves	Provoz River	2.0
Santa Luzia	Manuel Jorge River	1.15
S. João	Cantador River	0.9
Santa Clara	Manuel Jorge River	0.89
Cruz Grande	Do Ouro River	0.88
Monte Verde	Xufexufe River	0.80
Mateus Sampaio	Umbugu River	0.50
Almeirim	Agua Grande River	0.44

Source: ALER[7]

RENEWABLE ENERGY POLICY

Policy development, expansion and improvement of the energy sector, customer services and public services delivery all fall within the Government's priorities. The Government has mobilized resources to restructure the energy sector in order to create a more attractive investment environment, particularly for private investment in renewable energy infrastructure. Ongoing programmes, carried out with the support of development partners, are the main line of action. At present, no incentives or financial mechanisms exist to support the development of renewable energy sources, including SHP. However, regulations on renewable energy and SHP plants specifically are being drafted with the support of national and international consultancies.[9]

The National Development Plan 2017–2021 set targets for renewable energy including a 30 per cent share in electricity generation by 2021 and a 50 per cent share by 2030. In 2020, renewable energy share in electricity generation was 5 per cent, indicating that the 2021 target will most likely be missed. The renewable energy sources prioritized by the country are hydropower, solar power and biomass. There is not much potential for wind power on the islands due to the steep slopes of its terrain. There have been 34 potential sites identified for approximately 63 MW of hydropower, 25 sites for solar power for over 62 MW and one site for biomass identified for 12.5 MW.[7]

In 2019, the Global Environment Facility (GEF) and the United National Industrial Development Organization (UNIDO) approved a USD 24.93 million grant, of which USD 1.58 million would come directly from GEF and the rest would come from co-financing. This grant, named the Promotion of Investments in Renewable Energy and Energy Efficiency in the Electricity Sector, has multiple aims focusing on technical assistance and training. Activities in the scope of this grant include UNIDO working directly with the Government of Sao Tome and Principe to create clear renewable energy policies and create any legislation required to achieve them, as well as preparing a National Sustainable Energy Investment Plan to present to potential investors in at least two investment forums.[7]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

With the support of the UNDP, the Promotion of Sustainable Development and Hydroelectric Production Interconnected or in an Isolated Grid, more commonly known as The Energy Project, was created in 2017. It secured USD 20.7 million from multilateral and private sources to help establish the required institutional and legal framework for hydropower investment and development in the country.[12] A set of activities is underway with the objective of removing both technical and institutional barriers, including:

- Organizational restructuring of the Department of Natural Resources and Energy;
- Creation of support mechanisms and incentives for independent producers of electricity from renewable sources;
- Development and implementation of the Water Law;
- Development of the National Forest Development Plan;
- Update of the Forest Law.

Development of regulations for the electricity sector include:

- Regulation of energy generation from different sources of renewable energy (hydropower, solar photovoltaics, biomass and wind power);
- Sanctioning regime applied to electric power producers;
- Regulation of connection of new producers to the grid.

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

The Government of Sao Tome and Principe has worked with several international banks, donors and organizations to secure funding for SHP. In 2018, the African Development Bank through its Sustainable Energy Fund for Africa approved a USD 1 million grant for the development of mini-hydropower in Sao Tome and Principe. The grant is to provide the necessary funding for feasibility studies and environmental impact assessments at potential SHP sites. The aim is that the information gathered by these studies will attract investors in the sector. The initial locations that these studies will take place are at the Monte Rosa, Monte Verde and Santa Irene potential project sites.[7,13]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The country's hydropower sector has significant potential for development, as shown in the studies carried out. Therefore, boosting development will require raising private funds, taking into account the legal instruments that are being developed to increase the share of hydropower in the national energy mix and minimize the country's environmental impact.

The major barriers to SHP development in Sao Tome and Principe include:

- Institutional constraints due to the lack of a national strategy for hydropower and other renewable energy sources;
- Lack of an Electricity Master Plan;
- Lack of legislation and adequate implementation of the recommendations of the 2008 study by CECI Engineering Consultants, Inc.

The major enablers for SHP development in Sao Tome and Principe include:

- Most of the SHP potential is untapped and many sites have already been identified with their respective capacities;

- Access to electricity in the country is not universal, particularly in rural or remote areas. SHP development in remote areas can bring electricity to communities that have been without;
- Currently, fossil fuels account for 95 per cent of electricity generation. SHP could be vital to achieve the goal of 50 per cent renewable energy by 2030.

REFERENCES

1. World Bank (2020). *Population, total – Sao Tome and Principe.* Available at https://data.worldbank.org/indicator/SP.POP.TOTL?locations=ST (Accessed 27 June 2022).
2. Encyclopædia Britannica (2021). *Sao Tome and Principe.* Available at https://www.britannica.com/place/Sao-Tome-and-Principe (Accessed 27 June 2022).
3. Ministry of Natural Resources and Environment (2007). National Adaptation Programmes of Action on Climate Changes. Available at https://unfccc.int/resource/docs/napa/stp01.pdf (Accessed 27 June 2022).
4. Freshwater Ecosystems of the World (FEOW) (2019). *S. Tome and Principe.* Available at https://www.feow.org/ecoregions/details/587 (Accessed 27 June 2022).
5. National Company of Water and Electricity (EMAE) (2021). *Relatórios e Contas – 2020.* Available at https://www.financas.gov.st/index.php/publicacoes/documentos/file/1342-relatorios-e-contas-2020-emae [in Portuguese] (Accessed 27 June 2022).
6. World Bank (2020). *Access to Electricity (% of population) - Sao Tome and Principe.* Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS?locations=ST (Accessed 28 June 2022)
7. Lusophone Renewable Energy Association (ALER) (2020). *Renewable Energy and Energy Efficiency in São Tomé and Príncipe - National Status Report.* Available at https://www.aler-renovaveis.org/contents/files/aler-relatorio-stp-nov2020.pdf (Accessed 28 June 2022).
8. National Company of Water and Electricity (2019). *Tarifários.* Available at https://www.emae.st/PT/clientes/tarifarios [in Portuguese] (Accessed 30 June 2022).
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. 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 (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.
12. African Development Bank (2018). *Sustainable Energy Fund for Africa Triggers Power Sector Reform in São Tomé & Príncipe through Mini-hydro Projects Support.* Available at https://www.afdb.org/fr/news-and-events/sustainable-energy-fund-for-africa-triggers-power-sector-reform-in-sao-tome-principe-through-mini-hydro-projects-support-18270 (Accessed 29 June 2022).
13. United Nations Development Programme (UNDP) (2019). *Energy Project Midterm Review.* Available at https://erc.undp.org/evaluation/evaluations/detail/9215 (Accessed 29 June 2022).

Contributing organizations

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