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ON SMALL HYDROPOWER

World Small Hydropower Development Report 2022

Western Africa

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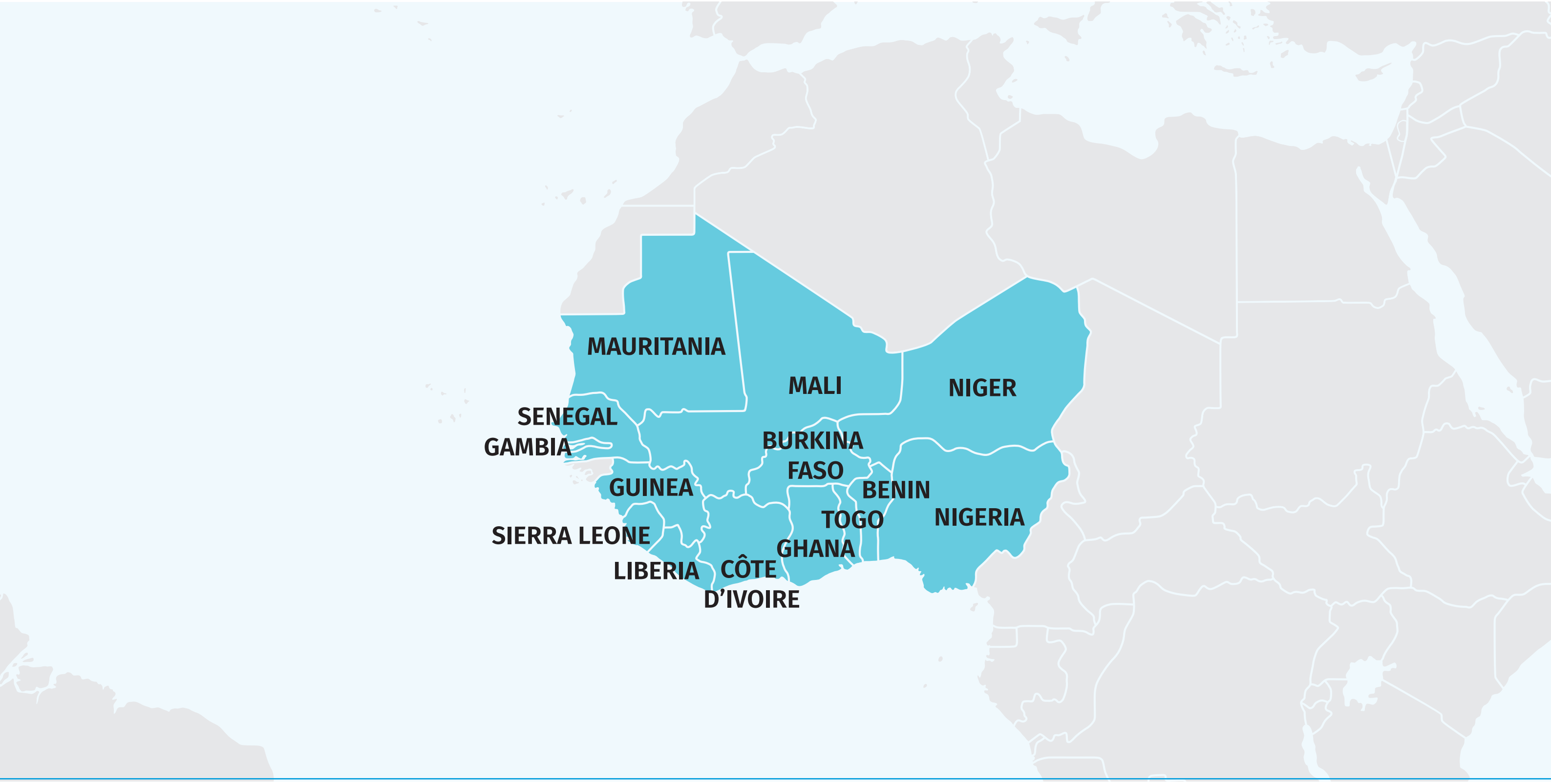


Western Africa

Countries: Benin, Burkina Faso, Cote d'Ivoire, Gambia, Ghana, Guinea, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo

INTRODUCTION TO THE REGION

The Western Africa region straddles the Sahel zone and includes areas with arid and semi-arid climates, as well as areas abundantly supplied with water resources. Several countries in the region are major oil producers and thermal power is the leading source of electricity generation across most of Western Africa with the exception of Guinea and Liberia, where hydropower is the primary source of generation. In Burkina Faso, Côte d'Ivoire, Ghana, Mali, Nigeria, Sierra Leone and Togo, hydropower plays an important supplementary role, and some minor hydropower capacity exists in Benin. Gambia, Mauritania, Niger and Senegal lack hydropower of any kind.

The majority of countries in Western Africa have nationwide electricity access rates below 50 per cent, and a significant gap exists between the rates of electricity access in urban and rural areas. The development of renewable energy sources (RES) is increasingly prioritized by countries in the region, in part as a means of closing this gap. RES other than hydropower are represented in the region primarily by solar power and bioenergy, while Mauritania and Senegal have additionally invested in considerable wind power capacities. The Economic Community of West African States (ECOWAS) has been working to promote RES development in member states through the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE).

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

Table 1. **Overview of Western 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)*
Benin	12	37	10	261	358	1	0
Burkina Faso	21	45	32	437	902	35	105
Côte d'Ivoire	26	49	N/A	2,229	10,613	879	3,481
Gambia	2	60	36	105	343	N/A	N/A
Ghana	32	86	74	5,172	18,189	1,580	7,252
Guinea	13	42	16	602	2,041	362	1,280
Liberia	5	28	8	193	226	92	124
Mali	20	51	16	884	3,952	315	1,463
Mauritania	5	46	3	587	863	N/A	N/A
Niger	24	19	13	380	555	N/A	N/A
Nigeria	206	55	26	17,823	33,489	2,017	8,211
Senegal	17	78	55	965	2,263	N/A	N/A
Sierra Leone	8	16	6	196	696	62	N/A
Togo	8	54	24	235	647	67	204
Total	-	-	-	**30,069**	-	**5,409**	-

Source: *WSHPDR 2022*[1]

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

REGIONAL SMALL HYDROPOWER OVERVIEW

The most commonly used definition of small hydropower (SHP) in Western Africa is the definition established by the ECOWAS that includes plants with an installed capacity of up to 30 MW. This definition is adhered to in Benin, Gambia, Liberia, Mali, Nigeria and Sierra Leone. The up to 10 MW definition of SHP is used in Cote d'Ivoire and Senegal, while Guinea adheres to the up to 1.5 MW definition and Ghana to the up to 1 MW definition. No official definition of SHP exists in Burkina Faso, Mauritania, Niger and Togo.

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

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

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed capacity (≤10 MW)*	*Potential capacity (≤10 MW)*
Benin	Up to 30 MW	0.5	95.0	0.5	5.0*
Burkina Faso	N/A	N/A	N/A	4.6	246.0
Côte d'Ivoire	Up to 10 MW	5.0	45.7	5.0	45.7
Gambia	Up to 30 MW	0.0	N/A	0.0	19.5
Ghana	Up to 1 MW	0.1	9.9	0.05	17.4
Guinea	Up to 1.5 MW	N/A	N/A	11.2	751.8
Liberia	Up to 30 MW	4.9	592.0	4.9	4.9**
Mali	Up to 30 MW	5.7	154.7	5.7	5.7**
Mauritania	N/A	0.0	N/A	0.0	N/A
Niger	N/A	0.0	N/A	0.0	8.0
Nigeria	Up to 30 MW	57.2	734.3	N/A	N/A
Senegal	Up to 10 MW	0.0	0.0	0.0	0.0
Sierra Leone	Up to 30 MW	12.2	N/A	12.2	639.0
Togo	N/A	N/A	N/A	1.6	137.0
Total	-	-	-	**45.7**	**1,880.0**

Source: *WSHPDR 2022*[1]

Note: *For SHP up to 1 MW. **Based on installed capacity.

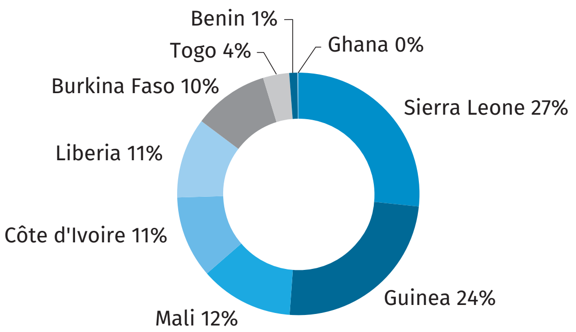
The total installed capacity of SHP up to 10 MW in Western Africa is 45.7 MW, while potential capacity is estimated at 1,880.0 MW. Relative to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity has increased by approximately 4 per cent due to the commissioning of one new SHP plant in Burkina Faso. Meanwhile, the estimated potential capacity of SHP up to 10 MW has more than tripled, mainly as a consequence of new data on the SHP potential in Burkina Faso and Guinea as well as a reinterpretation of available data on the SHP potential in Sierra Leone.

Overall, SHP plays a relatively small role in the electricity generation of the countries in Western Africa. Across much of the region, existing hydropower capacities mostly comprise large hydropower plants, although in Sierra Leone SHP accounts for nearly 20 per cent of all hydropower capacity, and the hydropower capacity of Benin is fully comprised of SHP. Several countries in the region have no hydropower of any kind and little prospect for hydropower development due to climatic conditions. New SHP construction in Western Africa in recent years has been very limited, with development focusing on other RES. The impact of the COVID-19 pandemic has likely played a role in constraining the resources available for the expansion of SHP capacity in the region during 2020–2022. Consequently, recent activity in the SHP sector has mainly consisted of studies collecting data on SHP potential.

It must be also noted that reliable data on the SHP sector for countries in Western Africa are often very difficult to acquire, both in the case of the countries surveyed in the current report and in the case of those not covered in the report due to lack of data. Consequently, the review of recent activities related to SHP development in the region is likely not exhaustive.

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 countries in the region is displayed in Figure 2.

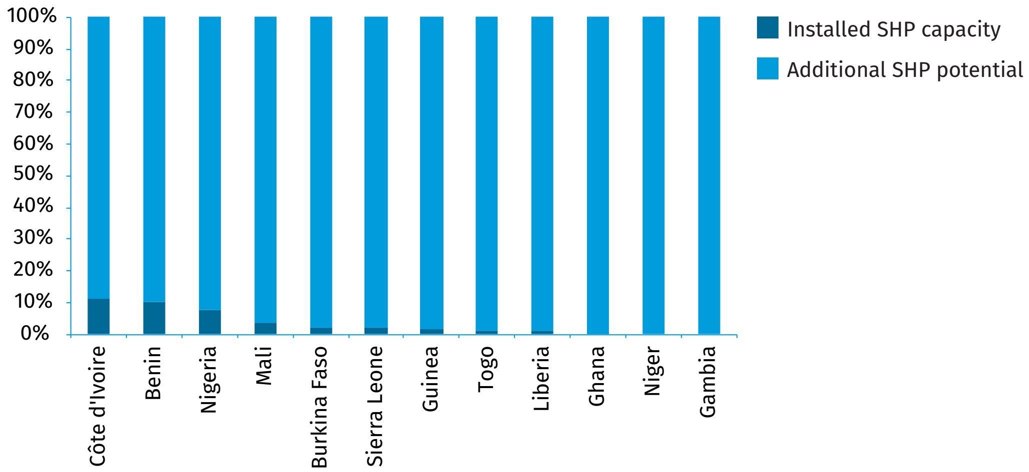
Figure 1. **Share of Regional Installed Capacity of Small Hydropower up to 10 MW by Country in Western Africa (%)**



Source: *WSHPDR 2022*[1]

Note: Gambia, Mauritania, Niger and Senegal not included due to a lack of SHP capacity; Nigeria not included due to a lack of data on existing capacities for SHP of up to 10 MW.

Figure 2. **Utilized Small Hydropower Potential by Country in Western Africa (%)**



Source: *WSHPDR 2022*[1]

Note: For SHP up to 10 MW, except in the case of Mali, Nigeria and Liberia, where the local definition is used due to lack of comprehensive data on the potential capacity of SHP up to 10 MW.

Benin has a single hydropower plant with an installed capacity of 0.5 MW. The potential capacity for SHP up to 30 MW is estimated at 95 MW, of which less than 1 per cent has been developed. Additionally, at least 5 MW of capacity for SHP up to 10 MW has been identified, of which 10 per cent has been developed. No recent activity in the country's SHP sector has taken place, although an upgrade to the existing SHP plant to raise its installed capacity to 1 MW has been considered.

The installed capacity of SHP up to 10 MW in **Burkina Faso** is 4.6 MW, provided by three SHP plants. The country's installed SHP capacity has recently doubled with the commissioning of a third plant in 2019. The potential capacity of SHP up to 10 MW is estimated at 246 MW on the basis of a recent study published in 2018, which identified a total of 80 potential SHP sites in the country. Specific plans exist outlining the construction of three additional SHP plants over the next several years.

The installed capacity of SHP up to 10 MW in **Côte d'Ivoire** is 5 MW, provided by a single SHP plant built in 1983, while the estimated potential SHP capacity is 45.7 MW, indicating that nearly 11 per cent has been developed. The country's installed SHP capacity has not changed in several decades. Additionally, the single existing SHP plant is non-operational and in need of refurbishment. No new projects in the SHP sector are under consideration, although some preliminary studies are planned.

There is no installed hydropower capacity in **Gambia** of any kind. The potential capacity for SHP up to 10 MW is estimated at 19.5 MW and remains entirely undeveloped. There are no SHP projects planned and recent activity in the SHP sector has been limited to updated studies of SHP potential, which have identified four potential SHP sites of up to 10 MW.

Ghana has a single SHP plant with an installed capacity of 0.045 MW. The potential capacity for SHP up to 10 MW is estimated at 17.42 MW, and at 9.9 MW for SHP up to 1 MW. Less than 1 per cent of SHP capacity under either definition has been developed. The sole operational SHP plant in the country was commissioned in 2020, and one earlier project has been on hold and requires extensive refurbishment. Sixty-nine potential sites up to 2 MW and another 12 sites up to 1 MW have been identified in the country, but there are no specific plans for new SHP construction.

The installed capacity of SHP up to 10 MW in **Guinea** is 11.2 MW, while the potential capacity has recently been estimated at 751.8 MW, indicating that approximately 1 per cent has been developed. There are five SHP plants in Guinea, with two undergoing renovation. As of 2021, feasibility studies were ongoing for the construction of four additional SHP plants with the support of the French Development Agency, and additional feasibility studies on several other potential sites are planned.

There are two operational SHP plants in **Liberia** with a total installed capacity of 4.86 MW. The potential capacity for SHP up to 30 MW in the country is estimated at 592 MW based on a study published in 2017, indicating that less than 1 per cent has been developed. No new construction in the SHP sector has taken place in recent years and there are currently no plans for additional SHP projects.

The installed capacity of SHP up to 30 MW in **Mali** is 5.7 MW, provided by a single plant. The potential capacity is estimated at 154.7 MW, indicating that nearly 4 per cent has been developed. Two new SHP plants are under development in the country through the Mini-Hydropower Plants and Related Distribution Networks Development Project, with environmental and social audits ongoing as of 2022. One additional SHP project has been initiated with the assistance of international development institutions.

There is no installed hydropower capacity of any kind in **Mauritania**, and no potential hydropower capacity has been documented. However, some limited SHP potential may exist in the southern part of the country.

There is likewise no installed hydropower capacity of any kind in **Niger**. A potential capacity of 8 MW for SHP of up to 10 MW has been identified but remains entirely undeveloped. There are no ongoing projects or plans for SHP development in Niger, although a large hydropower project of 130 MW is under construction.

The installed capacity of **Nigeria** for SHP up to 30 MW is estimated at 57.2 MW, with the decrease relative to the *WSHPDR 2019* reflecting more accurate data on existing SHP plants. There are 14 SHP plants operating in the country. The economically feasible potential capacity has been assessed at 734.3 MW from 278 potential sites, indicating that nearly 8 per cent has been developed, while the theoretical potential capacity is estimated at 3,500 MW. Several new SHP projects have been initiated in Nigeria over the last decade, but their status and stage of completion are unclear.

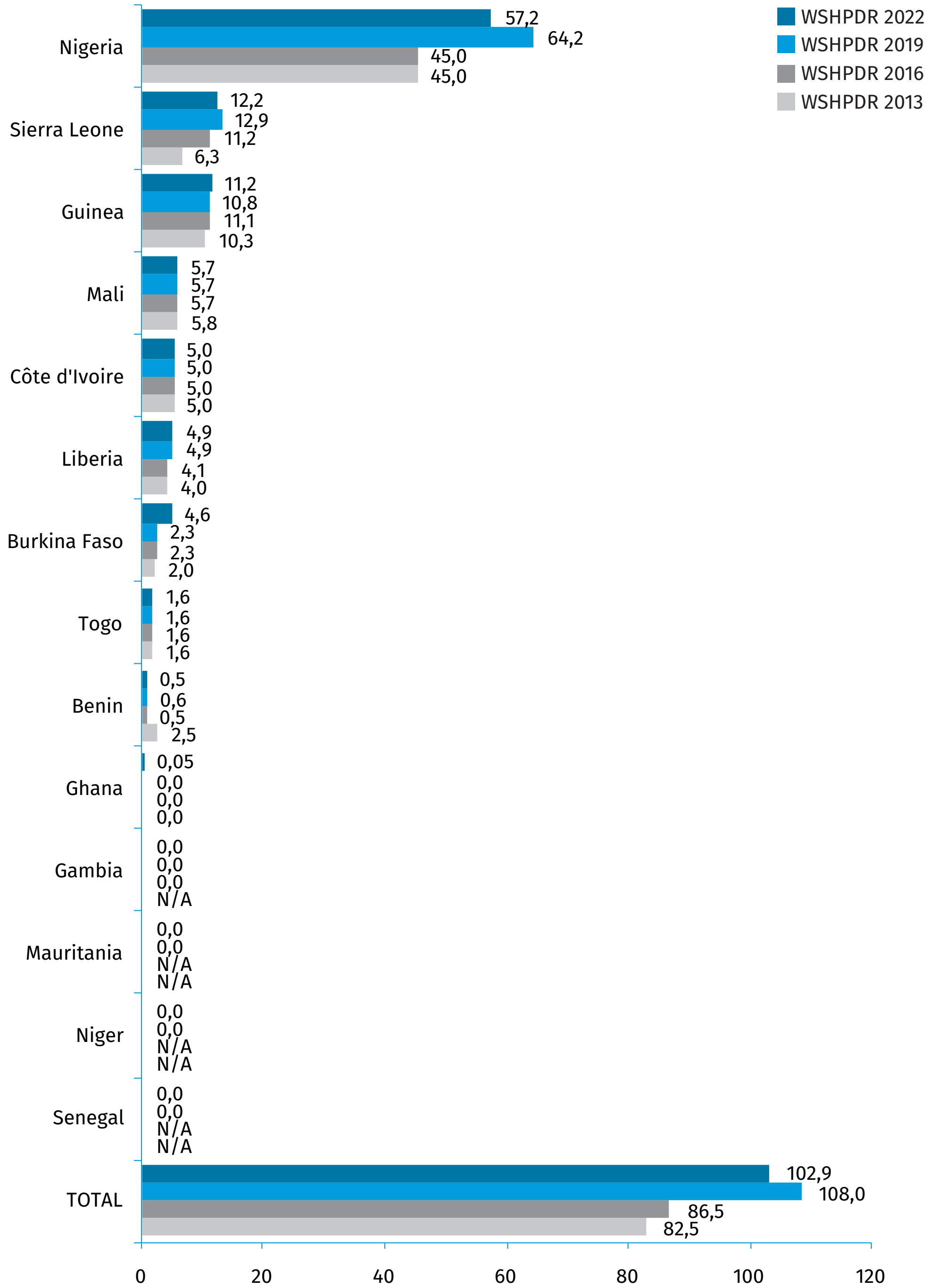
There is no installed hydropower capacity of any kind in **Senegal**, and no potential SHP capacity has been identified due to the flat topography of the country.

There are eight SHP plants of up to 30 MW in **Sierra Leone** with a total installed capacity of 12.15 MW. Potential capacity for SHP up to 30 MW is estimated at 639 MW, indicating that approximately 2 per cent has been developed. One new SHP plant with a capacity of 15.4 MW has been in development since 2016.

There is one SHP plant in **Togo** with an installed capacity of 1.6 MW. Potential capacity for SHP up to 10 MW is estimated at 137 MW, indicating that approximately 1 per cent has been developed, while potential for SHP up to 30 MW is estimated at 206 MW, of which less than 1 per cent has been developed. There are no ongoing SHP projects in the country, although the Government has identified seven potential sites for priority development.

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

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



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

Note: For SHP up to 10 MW, except in the case of Nigeria, where the local definition is used due to lack of data on the installed capacity of SHP of up to 10 MW.

Climate Change and Small Hydropower

Precipitation and runoff in Western Africa have been highly variable over the last century. Projections of future runoff in the region are likewise uncertain. Runoff in certain countries, including Guinea, is projected to decrease, while in Gabon and Sierra Leone it is projected to increase. Development of additional hydropower capacity in the region is seen as essential to reaching a clean energy mix and universal electricity access, but increasing the share of hydropower without assessing the potential impacts of climate change may increase the exposure of countries in the region to climate hazards and put their energy security at risk. Nevertheless, studies in the Upper Niger and Bani River basins have highlighted potential solutions aimed at reducing high streamflow variability and loss of water resources. In particular, results suggest that operating hydropower facilities as run-of-river projects could reduce evaporation by 20 per cent.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The development of SHP in **Benin** is complicated by low and unstable streamflow in the country's rivers, as well as by a lack of institutional and regulatory frameworks, incentives for SHP development and local technical capacity. Additionally, the country has prioritized RES other than SHP in its renewable energy strategy. At the same time, the considerable untapped SHP potential, particularly for SHP up to 30 MW, may form the basis for feasible SHP projects in areas where electricity access is lacking.

The development of SHP in **Burkina Faso** is likewise hampered by unpredictable streamflow and droughts that are exacerbated by ongoing climate change. The country lacks incentives for SHP development, and lack of reliable information on SHP potential likewise discourages investments. Government support has instead focused on solar power, which is seen as a more sustainable and profitable option. Enablers for SHP development include the recently identified additional SHP potential as well as the country's experience with hydropower in general, including technical capacity in the design, manufacture and operation of hydropower plants.

The key barriers to SHP development in **Côte d'Ivoire** are the lack of comprehensive data on potential SHP sites and the country's heavy focus on the development of large hydropower. At the same time, the SHP potential in the country is considerable, and SHP could play an expanded role as the basis for micro-grids used to extend electricity access to remote areas.

Development of SHP in **Gambia** is hampered by the low heads found across the country's hydrology system, which complicates any hydropower development. Additional barriers include the institutional and operational weaknesses of the country's distribution and transmission system operator and high electricity tariffs, which make electricity unaffordable for large segments of the population and thus limit the economic feasibility of potential projects. Enablers include recent studies on SHP potential and the availability of incentives for SHP development in the form of feed-in tariffs (FITs).

Barriers to SHP development in **Ghana** include weak institutional and regulatory frameworks, limited local expertise and awareness of SHP, lack of funding opportunities and climate change impacts that interfere with hydropower generation. At the same time, a wide array of potential SHP sites has been identified in the country. The overall policy direction in Ghana is favourable towards SHP development and includes support in the form of FITs and other incentives.

Barriers to SHP development in **Guinea** include a lack of financial support and the low marketability of electricity from SHP due to the poverty of the rural population, as well as institutional shortcomings and lack of technical capacity in the sector. However, the undeveloped SHP potential in the country is considerable and well-documented. Some of this potential may be realized with the aid of international development agencies.

Development of SHP in **Liberia** is hampered by a lack of a comprehensive renewable energy policy or strategies for SHP development, deficient electricity grid, lack of local technical expertise and insufficiently detailed hydrological data. At the same time, there is considerable and well-documented untapped SHP potential in the country and recent government documents have made mention of plans to accelerate SHP development.

In **Mali**, SHP development is complicated by high investment costs, variability in river flow caused by climate change and concerns over environmental impacts, which have generated opposition from indigenous groups. Enablers for SHP development include the considerable untapped SHP potential and the availability of international financing, as well as interest on the part of the Government in promoting mini-grids and the job creation potential of SHP projects.

The lack of identified hydropower potential in **Mauritania** is a major impediment to SHP development in the country. The

Government has consequently focused on developing other RES such as solar power and wind power. However, if properly assessed, the suspected SHP potential in the southern part of the country may be used to provide power to isolated rural communities.

In **Niger**, the lack of experience with hydropower development and the country's irregular rainfall patterns, exacerbated by climate change, are the major obstacles to SHP development. Additional obstacles include a lack of a comprehensive renewable energy policy and dependence on fossil fuels for electricity generation. At the same time, the identified SHP potential could provide a means of improving electricity access, particularly if regional expertise in SHP could be attracted to develop this potential.

Barriers to SHP development in **Nigeria** include inadequate policy, institutional and regulatory frameworks, high investment costs and insufficient local technical capacity, lack of interest from the private sector in SHP development and limited access to available data on SHP potential. The main enablers are the very considerable and well-documented SHP potential and the urgent need to extend electricity access to remote parts of the country.

The main barrier to SHP development in **Senegal** is the country's flat topography and lack of any SHP potential. At the same time, if any SHP potential could be identified, it would benefit from a strong institutional framework and government support for RES development, which includes tax incentives and FITs.

Barriers to SHP development in **Sierra Leone** include a lack of funding and lack of local technical and manufacturing capacity, as well as high electricity tariffs that make electricity cost-prohibitive for many segments of the population. However, the country's considerable potential SHP capacity could be realized through international assistance and direct foreign investment, which have already made a positive impact in the solar power sector.

In **Togo**, obstacles to SHP development include barriers to the entry of private investors, institutional and regulatory weaknesses, relatively high up-front costs compared to diesel generators and lack of international funding opportunities. At the same time, the country has significant untapped SHP potential due to favourable hydrological conditions, and the Government has prioritized SHP development as part of rural electrification efforts, as well as attracting private investors to the SHP sector.

REFERENCES

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

Benin

Salim Chitou, West-African Energy Information System

KEY FACTS

Population	12,114,193 (2020)[1]
Area	114,763 km^2 [2]
Topography	The topography of Benin can be subdivided into five regions: the flat, low and sandy coastal region; the central hilly plain rising gradually to 200–400 metres from south to north; the Kandi Basin in the north-east, which is a plain drained by the Sota River and its tributaries; the Atakora Mountains lying in the north-west and peaking at Mount Sokbaro (658 metres); and the vast plains of Gourma in the extreme north-west.[2]
Climate	The climate of Benin is strongly influenced by the West African Monsoon. In the south, where the monsoon regime predominates (humid winds from the south-west), the climate is of the subequatorial type and is characterized by two rainy seasons and two dry seasons. In the north of the country, where the influence of the monsoon is more moderate, the climate is tropical continental, with one rainy season and one dry season. Air temperatures average 27.2 °C, with absolute maximums that can exceed 45 °C in the north.[3]
Climate Change	Benin is highly vulnerable to climate change. Since 1960, average temperature increased by 1.1 °C. The number of hot days per year increased by 39, whereas the frequency of cold days and nights decreased significantly. Annual precipitation decreased by 180 mm, resulting in more intense droughts. At the same time, rains intensified, leading to soil erosion and floods. The mean annual temperature is projected to increase by 1.0–3.0 °C by the 2060s and by 1.5–5.1 °C by the 2090s.[4]
Rain Pattern	Average annual precipitation ranges between 700 mm in the extreme north and 1,400 mm in the extreme south-east. There is also a transitional zone, where, depending on the year, the rainfall regime is bimodal as in the south of the country or mono-modal as in the north, with an average annual rainfall of 1,000–1,200 mm.[4]
Hydrology	Hydrologically, Benin can be divided into four major basins: the Niger Basin, the Ouémé-Yéwa Basin, the Volta Basin and the Mono-Couffo Basin. The Niger Basin comprises the Niger (120 kilometres), Mékrou (410 kilometres), Alibori (338 kilometres) and Sota (250 kilometres) Rivers. The Ouémé-Yéwa Basin includes the Ouémé River (510 kilometres) and its main tributaries the Okpara (200 kilometres) and Zou (150 kilometres), as well as Porto-Novo Lagoon (35 km^2) and Lake Nokoué (150 km^2). The Volta Basin includes the Volta (1,500 kilometres) and Pendjari (380 kilometres) Rivers. Finally, the Mono-Couffo Basin includes the Mono (100 kilometres) and Couffo (190 kilometres) Rivers, lakes Ahémé (78 km^2) and Toho (15 km^2) and Cotonou and Grand-Popo (15 km^2) Lagoons.[4]

ELECTRICITY SECTOR OVERVIEW

The total installed electricity capacity of Benin in 2019 was 261 MW, with over 98 per cent coming from thermal power. There is one hydropower plant installed on the territory of Benin, the 0.5 MW Yeripao plant, as well as 3.75 MW of capacity from micro-scale solar photovoltaics (PV) (Figure 1).[5] An additional 32.5 MW comes from the 65 MW Nangbeto hydropower plant installed on the Mono River in Togo, which is jointly owned by Benin and Togo under the bi-national Communauté Électrique du Benin (CEB).[5,6]

Total electricity generation in 2019 in Benin amounted to 357.5 GWh, coming predominantly from thermal power and to a lesser extent from solar power (Figure 2).[5] Conversely, the Yeripao hydropower plant did not contribute to the country's electricity supply as it remains offline.

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

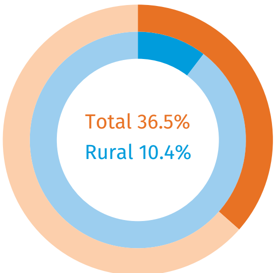
Source: SIE-Benin[5]

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

Source: SIE-Benin[5]

Total access electricity in the country in 2020 stood at approximately 37 per cent, including 65 per cent in urban areas and 10 per cent in rural areas (Figure 3).[7]

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



Source: DGRE[7]

The limited capacity of the country's energy sector to meet demand remains a major challenge for the public authorities. Until recently, the country's energy situation was characterized by a recurrent crisis marked by insufficient electricity supply, the relatively high cost of electricity, low energy efficiency, not to mention the weak development of alternative energy sources. These factors have made the sector particularly vulnerable and have negatively impacted the national economy. Hence, one of the key development objectives for Benin is to increase electricity production. The main recent development was the construction of the 127 MW Maria-Gléta thermal power plant, which was launched in 2019.[8] Benin and Togo jointly planned to develop the 147 MW Adjarala hydropower plant on the Mono River, however, the project stalled due to financing issues.[9] Currently, the Government plans to develop the 140 MW Glo-Djigbe thermal power plant, 100 MW of solar power capacity, the 128 MW Dogo hydropower plant and other projects.[10]

The main players of the electricity sector in Benin are the Ministry of Energy and the structures under its supervision, the Electricity Regulatory Authority (ARE), the Benin Agency for Rural Electrification and Energy Management (ABERME), the regional cooperation institutions, private structures responsible for the production, transmission, distribution and marketing of electrical energy and energy efficiency as well as consumer associations and professional organizations.

Electricity tariffs in Benin are uniform across the entire territory and remained unchanged between 2006 and 2019, but were adjusted for 2020 and 2021 (Table 1).

Table 1. **Low-Tension Electricity Tariffs in Benin in 2019–2021**

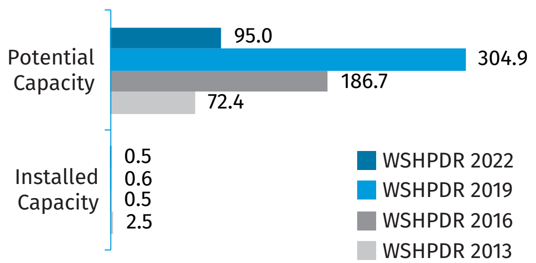
	2019 tariffs		*2020 tariffs*		*2021 tariffs*	
Consumer category	*Electricity usage (XOF/kWh (USD/kWh))*	*Fixed charge (XOF/kVA/M (USD kVA/M))*	*Electricity usage (XOF/kWh (USD/kWh))*	*Fixed charge (XOF/kVA/M (USD kVA/M))*	*Electricity usage (XOF/kWh (USD/kWh))*	*Fixed charge (XOF/kVA/M (USD kVA/M)*
Domestic:						
<20 kWh	78	500	78	500	86	500
0–250 kWh	109	500	114	500	125	500
>250 kWh	115	500	134	500	148	500
Professional and prepaid	111	500	114	500	125	500

Source: SBEE[11]

SMALL HYDROPOWER SECTOR OVERVIEW

The official definition of small hydropower (SHP) in Benin is up to 30 MW. There is one SHP plant in Benin, the 0.5 MW Yeripao plant (Table 2).[5] In 2016, the plant generated 5.3 MWh and in 2017, 1.2 MWh, with no generation since then. Renovations have been considered for the Yeripao plant to reach a capacity of 1 MW, however, the project was not realized. The SHP potential up to 30 MW is estimated at approximately 95 MW.[12] Compared to the *World Small Hydropower Development Report* (*WSHPDR*) *2019*, the installed capacity decreased based on more accurate data. The potential estimate also decreased based on a more recent assessment (Figure 4).

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



Sources: SIE-Benin,[5] ECREEE,[12] *WSHPDR 2013*,[13] *WSHPDR 2016*,[14] *WSHPDR 2019*[15]

A number of studies of the hydropower potential in Benin have been carried out identifying a range of potential sites of various scale. In 2012, the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) reported a total potential of 304.9 MW from 99 sites of up to 30 MW each, with the estimate being based on a number of earlier inventories.[16] Another assessment was carried out in 2015 under the ECOWAS Small-Scale Hydropower Programme using Geographic Information Systems (GIS) and identified 5 MW of potential for sites of up to 1 MW and 90 MW of potential for 1–30 MW sites.[12] The present chapter uses the more recent estimate of the potential.

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

Name	*Locatiion*	*Capacity (MW)*	*Operator*	*Launch year*
Yeripao	Yeripao, Natitingou	0.5	Benin Electric Energy Company (SBEE)	1997

Source: ECREEE[16]

RENEWABLE ENERGY POLICY

Benin is endowed with significant renewable energy resources, however, only a minor share of the existing potential is currently used. This issue is addressed in the National Policy for the Development of Renewable Energy (PONADER) 2020–2030, which was adopted by the Government on 14 October 2020. The ambition of the PONADER is in particular to improve knowledge of the renewable energy resources in the country, to promote technologies for the assessment of the existing potential, to reduce energy imports and to increase energy access in rural areas. The PONADER also set the target of reaching 20–30 per cent of electricity generation from renewable energy sources and 30–40 per cent of total installed capacity.[17] The Policy is aligned with the Government Action Programme (PAG), which among other objectives envisages improving the legislative and regulatory system in each sector in order to attract private investments.[10]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Several barriers to SHP development exist in Benin, including:

- Lack of local hydropower equipment, supply and local manufacturers;
- Lack of an institutional and regulatory framework facilitating licences, permits, authorizations and buy-back tariffs;
- Low-flow and drying rivers;
- Independent power producers have not yet explored the option of SHP;
- Lack of a feed-in tariff (FIT) for SHP;
- Policy focus on other renewable energy sources and large-scale hydropower.

At the same time, SHP development in the country could be possible given the following factors:

- Significant SHP potential remains untapped;
- Low electrification rates, particularly in rural areas.

REFERENCES

1. National Institute of Statistics and Demography (INStaD) (2021). Statistiiques Demographiques. Available at https://instad.bj/statistiques/statistiques-demographiques [in French] (Accessed 15 July 2022).
2. Encyclopaedia Britannica (n.d.). *Benin*. Available at https://www.britannica.com/place/Benin (Accessed 15 July 2022).
3. Ministry of the Living Environment and Sustainable Development (n.d.). *Troisieme communication nationale du Benin a la convention cadre des nations unies sur les changements climatiques.* Available at https://www4.unfccc.int/sites/SubmissionsStaging/NationalReports/Documents/39685271_Benin-NC3-1-BENIN_TCN_2019.pdf [in French] (Accessed 15 July 2022).
4. Ministry of Foreign Affairs off the Netherlands (2018). *Climate Change Profile: Benin.* Available at https://reliefweb.int/report/benin/climate-change-profile-benin#:~:text=The%20expected%20impact%20of%20climate,sharp%20rise%20in%20sea%20level. (Accessed 15 July 2022).
5. Benin's Energy Information System (SIE-Benin) (2019). *Base de données*. Available at http://sie.uemoa.int/siebenin/ [in French] (Accessed 15 July 2022).
6. Communauté Electrique du Bénin (CEB) (n.d.). *Official website*. Available at http://cebnet.org (Accessed 15 July 2022).
7. General Directorate of Energy Resources (2021). Chiffres Clés 2021: Bilans Énergétiques et indicateurs 2016 à 2020. Available at https://direction-energie.gouv.bj/telecharger-chiffres-cles [in French] (Accessed 15 July 2022).
8. Caisse Autonome d'Amortissement (CAA) (n.d.). *Maria-Gléta power plant.* Available athttps://www.caa.bj/en/government-action-program/energy/maria-gleta-power-plant/ (Accessed 15 July 2022).
9. Netherlands Commission for Environmental Assessment (2019). *099-i. Advisory review ESIA Hydropower Adjarala report - Benin, Togo*. Available at https://www.eia.nl/en/projects/099-i (Accessed 15 July 2022).
10. President of the Republic of Benin (n.d.). Électricité: Projets. Available at https://beninrevele.bj/secteur/electricite/ [in French] (Accessed 15 July 2022).
11. Benin Electric Energy Company (SBEE) (2021). *Important communique de la SBEE / ajustement tarifaire*. Available at https://www.sbee.bj/site/important-communique-de-la-sbee-ajustement-tarifaire/ [in French] (Accessed 15 July 2022).
12. Economic Community Of West African States Centre for Renewable Energy and Energy Efficiency (2012). *GIS Hydropower Resource Mapping and Climate Change Scenarios for the ECOWAS Region, Country Report for Benin*. Available at http://www.ecowrex.org/sites/default/files/country_report_01_benin.pdf (Accessed 15 July 2022).
13. UNIDO, ICSHP (2013). *World Small Hydropower Development Report 2013.* United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
14. UNIDO, ICSHP (2016). *World Small Hydropower Development Report 2016.* United Nations Industrial Development Organization, Vienna, Austria; International Center on Small

Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.

15. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019.* United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
16. Economic Community of West African States Centre for Renewable Energy and Energy Efficiency (2012). *Baseline Report on existing and potential small-scale hydropower systems in the ECOWAS region*. ECOWAS, UNIDO. Available at http://www.ecreee.org/sites/default/files/documents/basic_page/ecowas-unido_sshp_baseline_report_0.pdf (Accessed 15 July 2022).
17. Ministry of Energy (n.d.). *Politique nationale de développement des énergies renouvelables*. Available at https://energie.gouv.bj/article/politique-nationale-de-developpement-des-energies-renouvelables [in French] (Accessed 15 July 2022).

Burkina Faso

International Center on Small Hydro Power (ICSHP)

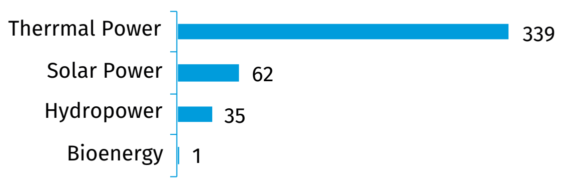
KEY FACTS

Population	20,903,278 (2020)[1]
Area	274,220 km² [2]
Topography	Burkina Faso is a landlocked country, bounded by Mali, Niger, Benin, Côte d'Ivoire, Ghana and Togo. It is situated on an extensive plateau, which is defined by a grassy savanna in the north that gradually becomes sparse forests in the south. A sandstone massif that covers most of the land is where the highest point of the country is, Mount Tena Kouron, at 747 metres. The lowest point of the country is the Black Volta River at 200 metres above sea level.[3]
Climate	Due to its location, Burkina Faso has a dry tropical climate. The climate alternates between a short rainy season and a long dry season. The country has three climatic zones: the Sahelian zone in the north, the North-Sudanian zone in the centre, and the South-Sudanian zone in the south.[4] April has the highest average temperature at 32 °C and the lowest average temperature is in January, at 25 °C.[5]
Climate Change	Burkina Faso is vulnerable to the impacts of climate change, particularly deforestation, desertification, low rainfall and extreme weather events. By 2050, a 1.4–1.6 °C rise in temperatures is expected in Burkina Faso.[6] By 2080–2099, temperature is projected to increase by 3–4 °C, which is substantially higher than the global.[5] Despite little projected change in annual precipitation sums, future dry and wet periods are likely to become more extreme.[6]
Rain Pattern	The Sahelian zone receives less than 600 mm of average annual rainfall. The North-Sudanian zone receives an average annual rainfall between 600 mm and 900 mm. The South-Sudanian zone receives an average annual rainfall above 900 mm.[3] Rainfall is heaviest in August, with an average of 231 mm, while the average annual precipitation is 816 mm.[5]
Hydrology	The three principal rivers are Black Volta (Mouhoun), the Red Volta (Nazinon) and the White Volta (Nakambé). These rivers all converge in Ghana to form the Volta River. The Oti, another tributary of the Volta, rises in south-eastern Burkina Faso.[6]

ELECTRICITY SECTOR OVERVIEW

In 2019, total electricity production in Burkina Faso reached 902 GWh, of which thermal power plants accounted for 82 per cent (Figure 1). The country is still highly dependent on electricity imports from Cote d'Ivoire, Ghana and Togo, having imported approximately 1,087 GWh in 2019.[7]

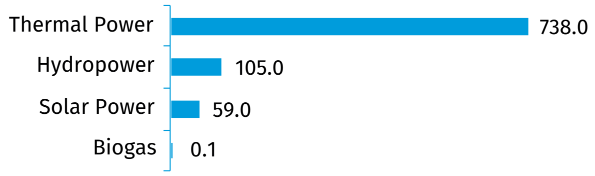
Figure 1. **Annual Electricity Generation by Source in Burkina Faso in 2019 (GWh)**



Source: ARSE[7]

In 2020, the total installed capacity in Burkina Faso was 437 MW, with thermal power (heavy fuel oil and distillate diesel oil) making up 78 per cent of the total and renewable energy sources accounting for the remaining 22 per cent (Figure 2).[8] Over the past years, the country has seen a significant increase in solar power capacity, with a number of new projects launched.[9]

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



Sources: IRENA[8]

The overall electricity losses in the country's electricity system amounted to 303 GWh in 2019, compared to 290 GWh in 2018, with most of the losses taking place in the distribution network. The overall efficiency of the electricity network improved from 84.4 per cent in 2018 to 84.8 per cent in 2019.[7]

The electricity demand of the country is constantly increasing and there are several projects under implementation aimed at improving the supply (Table 1). In 2019, agreements were signed with six independent power producers (IPPs) for the construction of solar power plants with a combined capacity of 140 MW.[7] The thermal power plant in Fada was also launched in 2020, contributing 7.75 MW to the country's installed capacity.[10] The country has also planned several other projects until 2030 as a commitment under its Nationally Determined Contribution.[11]

Table 1. **List of New Electricity Generation Projects under Implementation in Burkina Faso in 2021**

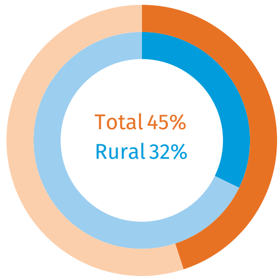
Project	*Planned capacity (MW)*	*Generation type*	*Connection*
Kossodo — expansion	55.0	Diesel thermal	Ongrid
Koudougou	20.0	Solar PV	Ongrid
Kaya	10.0	Solar PV	Ongrid
Kodeni	38.0	Solar PV	Ongrid
Pâ	30.0	Solar PV	Ongrid
Kalzi	36.0	Solar PV	Ongrid
Kodeni	18.0	Solar PV	Ongrid
Zano	24.0	Solar PV	Ongrid
Dedougou	30.0	Solar PV	Ongrid
Gosin (Ouaga Nord-West)	42.0	Solar PV	Ongrid
Gaoua	1.0	Solar PV	Ongrid
Diapaga	2.0	Solar PV	Ongrid
Dori	6.0	Solar PV	Ongrid

Source: ARSE,[7] MAN[12]

The energy sector in Burkina Faso is controlled by the Ministry of Energy, Mines and Quarries. The Regulatory Authority of Energy Sector (ASS) is responsible for regulation, control and monitoring of operators in the energy sector, while the Electricity Sector Regulatory Authority (ARSE) is the electricity sector regulator. The National Electricity Company of Burkina Faso (SONABEL) is the state-owned utility responsible for electricity generation, transport, distribution, import and export. As per the Electricity Law promulgated in 2017, SONABEL has lost monopoly in all subsectors except for electricity transport. The Rural Electrification Agency (ABER), created to replace the Rural Electrification Fund (FDE), aims to promote rural electrification in the country. The National Agency for Renewable Energy and Energy Efficiency (ANEREE) promotes and coordinates all operations aimed at promoting renewable energy and energy efficiency.[9]

Burkina Faso is one of the least electrified countries globally.[13] However, the electrification rate has been steadily increasing since 2010. In 2018, 45 per cent of the population had access to electricity (Figure 3). In urban centres, the electrification rate was 75 per cent, while in rural areas it was 32 per cent.[7] While more recent data on the country's electrification rate are not available, there has been a significant increase in rural electrification form 3 per cent in 2017 to 32 per cent in 2018.[7] By 2030, the Government aims to reach 95 per cent electricity access, including 50 per cent in rural areas, as well as 100 per cent and 65 per cent access to clean cooking solutions in urban and rural areas, respectively.[13]

Figure 3. **Electrification Rate in Burkina Faso in 2018 (%)**



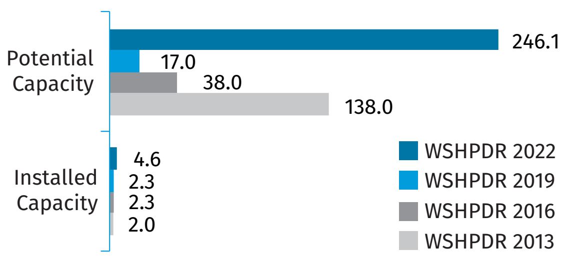
Source: ARSE[7]

The average electricity selling price in 2019 was 116.16 CFA/kWh (approximately 0.20 USD/kWh), 5 per cent less than in 2015. This was still below the cost of electricity generation of 139.11 CFA/kWh (0.24 USD/kWh), which results in a subsidy of CFA 22.96 (USD 0.04) per kWh consumed.[7]

SMALL HYDROPOWER SECTOR OVERVIEW

There is no official definition of small hydropower (SHP) in Burkina Faso. For the purposes of this chapter, SHP will be considered as plants up to 10 MW. As of 2021, there were three operational SHP plants with a combined capacity of 4.6 MW: Niofila (1.5 MW), Samandeni (2.6 MW) and Tourni (0.5 MW) (Table 2).[14,15,16] The change in installed capacity compared to the *World Small Hydropower Development Report (WSHPDR) 2019* is due to the launch of the Samendeni plant in 2019 (Figure 4). The estimate of the SHP potential has also increased based on a more recent study, which suggests a total potential of 246.1 MW. This includes 232.9 MW from 42 potential sites of 1.01–10 MW of capacity and 13.2 MW from 38 sites of 0.1–1 MW of capacity.[17]

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



Source: IRENA,[14] Africa Energy Portal,[15] Moner-Girona et al.,[16] Korkovelos et al.[17] *WSHPDR 2013*,[18] *WSHPDR 2016*,[19] *WSHPDR 2019*[20]

The Samendeni hydropower plant was launched in 2019 and is part of the Samendeni Valley Integrated Development Programme, an initiative by the Government of Burkina Faso.[15] The Government also expressed interest in conducting feasibility studies for the development of another three hydropower plants: the 5.0 MW Gongourou plant, 5.1 MW Bontioli plant and 7.8 MW Bon plant. The Ministry of Energy, Mines and Quarries declared the aforementioned projects as a priority for the sustainable development of the country. Commitments have also been made towards the construction of the Gongourou and Bontioli plants.[14]

Most of the hydropower projects planned or under construction are located on the Black Volta River.[21] Table 3 offers more information with regards to the Government's development initiatives in the hydropower sector.

Table 2. **List of Existing Small Hydropower Plants in Burkina Faso**

Name	*Installed capacity (MW)*	*Type*	*Launch year*
Samandeni	2.6	Reservoir	2019
Niofila	1.5	Run-of-river	1996
Tourni	0.5	Run-of-river	1996

Source: IRENA,[14] Africa Energy Portal,[15] Moner-Girona et al.[16]

Table 3. **List of Planned Hydropower Projects in Burkina Faso as of 2021**

Name	*Potential capacity (MW)*	*Planned launch year*	*Status*
Noumbiel	60.0	2025	Planned
Aval	14.0	2023	Committed
Bougouriba	12.0	2025	Planned
Folonzo	10.8	2022	Committed
Bontioli	5.1	2022	Committed
Gongourou	5.0	2022	Committed

Source: IRENA[14]

RENEWABLE ENERGY POLICY

The National Policy for Sustainable Economic and Social Development outlined the strategy and actions of the Government of Burkina Faso for the period 2016–2020 to achieve its development objectives. The strategy mentions opting unequivocally for a transition towards green and renewable energy, in particular solar energy. In 2017, production and distribution of electricity in the country became open to private investors and SONABEL no longer has a monopoly over electricity production. Although power generation has been opened to the private sector, very few private investments have been made so far. As part of the Government's efforts to promote renewable energy and energy efficiency, ANEREE was established in 2016.[16]

Information in the field of renewable energy policy in Burkina Faso is enclosed in the Energy Sector Policy for the years from 2014 to 2025. The objectives the Government set in the Renewable Energy and Energy Efficiency Action Plans envisage Burkina Faso reaching 50 per cent renewable energy in the electricity mix by 2030, excluding biomass production.[13]

SHP projects are generally seen as more environmentally and socially acceptable in Burkina Faso and do not face negative social reaction as is often the case with large hydropower plants. The Government of Burkina Faso has been shown to be more invested in developing solar photovoltaic (PV) systems to increase electrification, particularly in rural areas, due to the country's climate which favours solar PV.

COST OF SMALL HYDROPOWER DEVELOPMENT

Based on the Bontioli, Gongourou and Samandéni projects, the investment costs for SHP projects in the country have been estimated at 11,006 USD/kW and the annual operation and maintenance cost at 330.2 USD/kW.[14]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

There are multiple barriers concerning SHP development in Burkina Faso. The most relevant ones include:

- Access to water as well as unpredictable climate conditions, with droughts affecting the regular flow of rivers and negatively influencing the profitability of potential SHP projects;
- The Government has mainly focused on solar power development in recent years, which is seen as a more sustainable and profitable solution, while SHP dissemination is not a priority;
- Lack of financial incentives such as feed-in tariffs and lack of sufficient information in the sector to attract potential private investors;
- Lack of reliable data from feasibility studies due to lack of funding and financial difficulties.[7,19]

Enablers for SHP development in Burkina Faso include:

- The hydropower sector development, including SHP projects, is actively encouraged by the Government, with a number of committed and planned SHP projects;
- Due to a number of existing hydropower plants in the country, there is experience in construction and operation of hydropower plants, as well as a qualified workforce for design, construction, operation and maintenance.

REFERENCES

1. World Bank (2020). *Population, total. Data. World Population Prospects: 2019 Revision.* Available at https://data.worldbank.org/indicator/SP.POP.TOTL?locations=BF (Accessed 15 November 2021).
2. World Bank (2016). *Surface area (sq. km). Data.* Available at https://data.worldbank.org/indicator/AG.SRF.TOTL.K2?locations=BF (Accessed 15 November 2021).
3. Encyclopaedia Britannica (2018). *Burkina Faso*. Available at https://www.britannica.com/place/Burkina-Faso#ref54877 (Accessed 15 November 2021).

4. United Nations Development Programme (UNDP) (2018). *Burkina Faso. Climate Change Adaptation*. Available at http://adaptation-undp.org/explore/western-africa/burkina-faso (Accessed 15 November 2021).
5. World Bank (2018). *Average Monthly Temperature and Rainfall for Burkina Faso from 1901-2015. Climate Change Knowledge Portal.* Available at http://sdwebx.worldbank.org/climateportal/index.cfm?page=country_historical_climate&ThisRegion=Africa&ThisCCode=BFA (Accessed 15 November 2021).
6. Climate Center (2021). *Burkina Faso*. Available at https://www.climatecentre.org/wp-content/uploads/RCCC-ICRC-Country-profiles-Burkina_Faso.pdf (Accessed 15 November 2021).
7. Electricity Sector Regulatory Authority (ARSE) (n.d.). *Rapport d'Activites 2019.* Available at https://www.arse.bf/IMG/pdf/rapport_arse_2019.pdf [in French] (Accessed 13 November 2021).
8. International Renewable Energy Association (IRENA) (2021). *Energy Profile: Burkina Faso*. Available at https://www.irena.org/IRENADocuments/Statistical_Profiles/Africa/Burkina%20Faso_Africa_RE_SP.pdf (Accessed 13 November 2021).
9. World Bank (2019). *Burkina Faso Electricity Access Project (P166785).* Available at https://documents1.worldbank.org/curated/en/889901551115559831/pdf/Concept-Project-Information-Document-PID-BURKINA-FASO-ELECTRICITY-ACCESS-PROJECT-P166785.pdf (Accessed 13 November 2021).
10. IMM (2020). *Inauguration of the Fada N'Gourma power plant (Burkina Faso)* Available at http://imm.energy/en/inauguration-of-the-fada-ngourma-power-plant-burkina-faso/ (Accessed 24 November 2021).
11. United Nations Framework Convention on Climate Change (2021). *Contribution Determinée au Niveau National (CDN) du Burkina Faso 2021–2025.* Available at https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Burkina%20Faso%20First/Rapport%20CDN_BKFA.pdf (Accessed 13 November 2021).
12. MAN Energy Solutions (n.a). *MAN Increases Generation Capacity in Burkina Faso by almost 20%.* Available at: https://www.man-es.com/company/press-releases/press-details/2020/06/18/man-increases-generation-capacity-in-burkina-faso-by-almost-20 (Accessed 24 November 2021).
13. SE4ALL Africa Hub (2018). *Burkina Faso.* Available at https://www.se4all-africa.org/seforall-in-africa/country-data/burkina-faso/ (Accessed 13 November 2021).
14. International Renewable Energy Association (IRENA) (2018). *Planning and prospects for renewable power: West Africa*. Available at https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Nov/IRENA_Planning_West_Africa_2018.pdf (Accessed 13 November 2021).
15. Africa Energy Portal (2019). *Burkina Faso: Samendeni hydroelectric dam officially operational in Bama*. Available at https://africa-energy-portal.org/news/burkina-faso-samendeni-hydroelectric-dam-officially-operational-bama (Accessed 15 November 2021).
16. Moner-Girona, M., Bódis, K., Korgo. B., Huld, T., Kougias, I., Pinedo-Pascua, I., Monforti-Ferrario, F. & Szabó, S. (2017). *Mapping the least-cost option for rural electrification in Burkina Faso - Scaling-up renewable energies,* Publications Office of the European Union, 2017, EUR 28514 EN, doi:10.2760/900097, JRC102198.
17. Korkovelos, A., Mentis, D., Siyal, S. H., Arderne, C., Rogner, H., Bazilian, M., Howells, M., Beck, H. & De Roo, A. (2018). A geospatial assessment of small-scale hydropower potential in sub-Saharan Africa. *Energies*, 11(11), 3100.
18. UNIDO, ICSHP (2013). *World Small Hydropower Development Report 2013.* United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
19. UNIDO, ICSHP (2016). *World Small Hydropower Development Report 2016.* United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
20. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
21. Mul, M., Obuobie, E., Appoh, R., Kankam-Yeboah, K., Bekoe-Obeng, E., Amisigo, B., Logah, F. Y., Ghansah, B., McCartney, M. (2015). *Water resources assessment of the Volta River Basin*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 78p. (IWMI Working Paper 166). doi: 10.5337/2015.220.

Côte d'Ivoire

N'guessan Pacôme N'Cho, Ministry of Petroleum, Energy and Renewable Energy

KEY FACTS

Population	25,716,544 (2019)[1]
Area	322,632 km^2[2]
Topography	Côte d'Ivoire is characterized by low terrain; the lands consist largely of plateaus and plains. The west highlands have few peaks beyond a thousand metres and the highest peak is Mount Nimba at 1,752 metres. In the remainder of the country, elevations generally vary between 100 and 500 metres, while most plateaus are approximately 200–350 metres.[3]
Climate	There are three main climatic regions: the equatorial coast in the south, the tropical forest in the middle and the semi-arid savannah in the north. Temperatures range from 10 °C to 40 °C, averaging 25-30 °C, but the country is generally subjected to large variations in temperature between the north and south and throughout the year. The south is generally warmer with high humidity between 80 and 90 per cent. The north is generally cooler with lower humidity between 40 and 50 per cent. Temperatures in the north change by up to 20 °C both daily and annually.[2]
Climate Change	Côte d'Ivoire is not yet seriously affected by climate change, but the balance could tip at any moment and harm the country's economy. Côte d'Ivoire could become one of the African continent's champions in adapting its economy to the phenomenon and mitigating its effects. Like the vast majority of countries on the African continent, the nation's contribution to the greenhouse effect is marginal. By 2050, it is projected that the country will be confronted with the combined effect of increase in temperatures (+2 °C), variation in rainfall (-9 per cent in May and +9 per cent in October), and rising sea levels (30 cm).[4]
Rain Pattern	The south has variable rainfalls between 2,100 mm and 2,500 mm. The middle central region has lower rainfalls of approximately 1,100 mm. The north is subject to a single rainy season lasting from April to October and peaking in August. The rainfall is higher in the north-west (approximately 1,600 mm) than in the north-east (approximately 100 mm). The western mountainous region is characterized by a nine-month rainy season (from February to October) with rainfall between 1,600 mm and 2,300 mm.[5]
Hydrology	The river system of Côte d'Ivoire has four main basins: the Cavally (700 km long with a drainage basin of 15,000 km^2); the Sassandra (650 km long with a drainage basin of 75,000 km^2); the Bandama (1,050 km long with a drainage basin of 97,000 km^2); and the Comoé, (1,160 km long with a drainage basin of 78,000 km^2). There are also several small coastal rivers: the Tabou, San-Pedro, Niouniourou, Boubo, Agnéby, Mé, Bia and Tanoé; and other smaller rivers such as the Gbanhala, Baoulé, Bagoué, Dégou, Kankélaba, Koulda, Gbanlou, Gougoulo and Kohodio.[6]

ELECTRICITY SECTOR OVERVIEW

Biomass dominates the energy sector of Côte d'Ivoire accounting for up to 70 per cent of overall energy needs.[7] Biomass fuels include: charcoal for households; firewood for households, small restaurants, bakeries and craft centres; agricultural and forest residues for the production of steam and/or electricity in some agro-industrial companies and sawmills.

In 2019, the total electricity generated from all sources was 10,612.8 GWh. This comprised 7,124.6 GWh from thermal power plants, 3,480.5 GWh generated from hydropower and 7.7 GWh from remote plants (Figure 1). Electricity sales to countries in the region amounted to 1,179 GWh, while energy purchases were estimated at 17 GWh.[8]

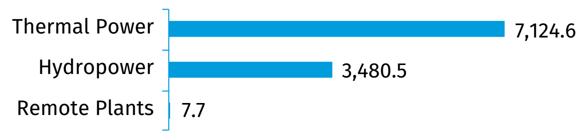
Figure 1. **Annual Electricity Generation by Source in Côte d'Ivoire in 2019 (GWh)**

Source: CIE[8]

Electricity generation in Côte d'Ivoire is from two main sources: hydropower contributing 879 MW of installed capacity (approximately 39.4 per cent) and thermal power plants contributing 1,350 MW (approximately 60.6 per cent) (Figure 2). The three following Independent Power Producers (IPPs) own 1,220 MW, or more than 92 per cent, of the total thermal power plant capacity: CIPREL (569 MW), Azito Energie (441 MW) and Aggreko (210 MW). There are also remote plants with generators running on diesel that supply some localities via mini-grids.[8] Their number decreased from 44 in 2018 to 40 in 2019 due to the connection of four localities to the interconnected grid. The installed capacity of these generators is 5,566 kVA or approximately 4.55 MW.

Since the end of 2017, the installed and available capacity supplying the interconnected electricity grid has been 2,229 MW. By March 2021, the installed capacity had not changed since the *World Small Hydropower Development Report (WSHPDR) 2019* in part due to projects being delayed due to COVID-19. The latest power plant in the country was commissioned on 2 November 2017. However, several electricity production units are scheduled for commissioning, including: the 37.5 MW solar photovoltaics (PV) project in Boundiali, which is scheduled to be commissioned in December 2021; the Azito thermal power plant (Phase 4) with combined cycle of 253 MW, the full commissioning of which is scheduled for April 2022; the GRIBOPOPOLI hydropower project of 112 MW, the commissioning of which is scheduled for the second quarter of 2023; and the SINGROBO-AHOUATY hydropower project of 44 MW and the associated energy evacuation network whose commissioning is scheduled for the first quarter of 2023.

Figure 2. **Installed Electricity Capacity by Source in Côte d'Ivoire in 2021 (MW)**



Source: CIE[8]

Out of a total of 8,518, the number of localities electrified in 2019 was 5,859 against 4,940 in 2018. This represented a coverage rate (ratio of the number of electrified localities to the total number of localities) of approximately 69 per cent in 2019 compared to 58 per cent in 2018. In terms of electricity access, the rate of the population living in an electrified area was approximately 94 per cent at the end of 2019 compared to 89.5 per cent in 2018.[9]

Regarding the distribution of electricity, there are two voltage levels for electricity subscribers: the low voltage is intended for households and the medium voltage is intended for companies or factories. The number of subscribers to the low-voltage electrical service increased by approximately 16 per cent between December 2018 and December 2019 from 2,191,290 to 2,532,418. Based on these data, it is estimated that the share of households with access to electricity was 49 per cent in 2019 compared to 44 per cent in 2018.[8] Information regarding rural electrification is not officially available due to the arbitrary nature of rural/urban distinctions in the country.

To accelerate the pace of improvement of the living conditions of the populations, the Government launched, following the instructions of His Excellency Mr. Alassane Ouattara, President of the Republic, the Government Social Programme (PSGouv) for the period 2019-2020. This programme was an intensifier of state social action and targeted all sectors.[10] Regarding access to electricity, the key outcomes of the programme were the reduction in the social tariff for the most disadvantaged households, improved rural electrification and connection/subscription at a lower cost. Thus, the main objectives of the PSGouv in terms of access to electricity were as follows: 1) the downward adjustment of 20 per cent of the nominal social tariff for the customers subscribing to the "social domestic" regime, in order to benefit from a reduction in the cost of electricity; 2) electrification of all of the 1,838 localities with more than 500 inhabitants by 2020 as part of the National Rural Electrification Programme (PRONER), with a target of 917 localities in 2019 and 921 in 2020; 3) facilitation of the connection/subscription to the national electricity grid of 400,000 households eligible for the Electricity For All Programme (PEPT) by the end of 2020, i.e. access to electricity for a population estimated at 2.4 million inhabitants.[9]

Under the technical supervision of the Ministry of Petroleum, Energy and Renewable Energy and the financial supervision of the Ministry for Economy and Finance, several public and private organizations are responsible for various activities in the electricity sector, including the General Directorate of Energy, which defines and implements the national energy policy. Two state companies are involved in the electricity sector: the Society of Energies of Côte d'Ivoire (CI-ENERGIES) and the National Electricity Sector Regulatory Authority (ANARE-CI). CI-ENERGIES is responsible for the planning and implementation of investment projects, while ANARE-CI plays the role of the electricity sector regulator. ANARE-CI was created by decree No. 2016-785 of 12 October 2016 and is vested with more extensive powers of decision, injunction, investigation and sanction to allow better regulation of the electricity sector.[11] As such, the missions assigned to it are in particular: to monitor compliance with laws and regulations as well as obligations resulting from authorizations or agreements in force in the electricity sector; to preserve the interests of users of the public electricity service and to protect their rights; to propose applicable tariffs to the Government in the electricity sector, including network access tariffs; to settle disputes in the electricity sector, in particular between operators and users; and to advise and assist the Government in the regulation of the electricity sector.

The Ivorian Electricity Company (CIE), established in 1990, is a private company responsible for the generation, transmission, distribution, export, import and management of electricity. It is linked to the state by a concession agreement for the public service of electricity for a period of 15 years, which was renewed in 2005 until 2020.[11] Three private operators (CIPREL, Azito Energie and Aggreko) are also involved in the sector as IPPs. They operate thermal power plants fuelled by natural gas supplied by PETROCI–C11, Foxtrot International and CNR International through contracts of sale and purchase signed with the Government.

The strengthening of electricity transmission and distribution infrastructure enabled the sector to have in 2019 an electrical grid with a total length of 54,017 km comprising: low-voltage lines measuring 22,523 km, medium-voltage (15 kV and 33 kV) lines measuring 25,432 km and high-voltage (90 kV and 225 kV) lines measuring 6,062 km.[8]

The Government has adopted a Strategic Development Plan 2011–2030, which covers the development of all sectors including the electricity sector. Within this framework, several projects have been planned concerning electricity generation, transmission and distribution infrastructure.

The electricity base tariffs are fixed by the Government upon the proposal of the regulator. Tariffs are the same for the entire country regardless of the region (Table 1).[12]

Table 1. **Electricity Tariffs under the Post-Payment Scheme in Côte d'Ivoire in 2019**

Tariff base	*Cost excluding 18 % VAT (CFA franc/kWh (USD/kWh)*
Social household low-voltage price (consumption ≤ 80 kWh in a two-month period)*	28.84 (0.057)
Social household low-voltage price (consumption > 80 kWh in a two-month period)	50.16 (0.100)
General household low-voltage price (consumption ≤ 180 kWh/kVA in a two-month period)	66.96 (0.133)
General household low-voltage price (consumption > 180 kWh/kVA by two-month period)	58.04 (0.116)
General professional low-voltage price (≤ 180 kWh/kVA)	86.31 (0.172)
General professional low-voltage price (> 180 kWh/kVA)	73.40 (0.148)

Source: ANARE-CI[11]

Note: *Exempt from VAT

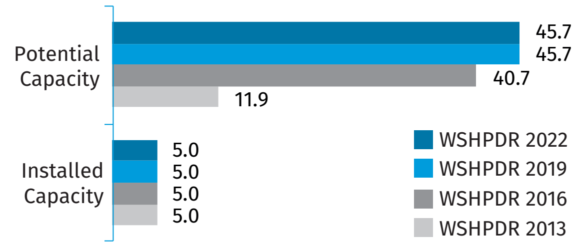
In addition to these base tariffs, there are additional taxes such as a fixed fee for a two-month period, a fee for rural electrification, the Ivorian Radio Television fee and local taxes that vary according to the electricity subscription and the region. Article 2 of Inter-ministerial Order No. 002 of 2 January 2019 stipulates that tariffs shall be revised upwards by 31 March of each year for application on July 1 of that year.[11]

SMALL HYDROPOWER SECTOR OVERVIEW

The official definition of small hydropower (SHP) is less than 10 MW as adopted by the General Directorate of Energy. The country's 5 MW of SHP installed capacity has remained unchanged since the *WSHPDR 2013*; however, estimated potential has increased by approximately 280 per cent, though remained unchanged since the *WSHPDR 2019* (Figure 3, Table 2).

There exists a single SHP plant Côte d'Ivoire, Grah/Faye, which was built in 1983.[13] Since 2018, the plant has been shut down and currently is in need of refurbishment. Thus, there was no available SHP capacity in the country as of Q1 2021.

Figure 3. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in Côte d'Ivoire (MW)**



Source: SIEREM,[13] *WSHPDR 2013*,[14] *WSHPDR 2016*,[15] *WSHPDR 2019*,[16] CIE[17]

Table 2. **List of Operational Small Hydropower Plants in Côte d'Ivoire**

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Plant type*	*Operator*	*Launch year*
Grah/Faye	35 km north of the town of San Pedro	5	10	Reservoir	CIE	1983

Source: SIEREM[13]

No SHP projects are currently underway. However, some preliminary studies are expected to be carried out, in particular those planned within the framework of the ENERGOS 2 project, which were delayed due to COVID-19.

Studies conducted in previous years have identified the most promising hydropower development projects. Table 3 consolidates data on sites with an estimated capacity less than 10 MW.[18,19] Based on these studies, dating back to 1979 (and to date the only studies), the total potential capacity for SHP is estimated at 45.7 MW suggesting that less than 11 per cent of the country's SHP potential has been developed. So far, these are the only studies conducted on SHP potential in the country.

Several large hydropower sites have been identified for a progressive development between 2017 and 2025: Soubré (275 MW), Singrobo (44 MW), Gribo-Popoli (112 MW), Boutoubré (156 MW), Louga (280 MW), Daboitié (91 MW), Tiboto (180 MW).[20] For hydropower of all sizes there is a total potential of 1.85 GW on the four major river basins, two times the current hydropower installed capacity.[11] The Soubré hydropower plant (275 MW) has been built and was officially put into service in November 2017. Regarding the Gribo-popoli (112 MW) and Singrobo (44 MW) hydropower plants, the Government has already signed concession agreements for their development.

Table 3. **Small Hydropower Sites Available for Renovation or Development in Côte d'Ivoire**

Name	*Location*	*Potential capacity (MW)*	*Head (m)*	*Type of site (new/ refurbishment)*
Grah/Faye	35 km north of the town of San Pedro	5.00	10.0	Refurbishment
Bandama	Haut Bandama	7.44	20.0	New
Lokpoho	Ferkessedou-gou	7.32	11.0	New
Bia	Aboisso	6.40	5.6	New
Lafigué	Korhogo	4.00	8.0	New
Comoé	Téhini	4.00	10.0	New
La palé	Boundiali	3.50	30.0	New
Drou	Man	2.56	162.0	New
Agnéby	Laouguié	2.01	21.0	New
N'zi	Fétékro	1.60	23.0	New
Banoroni	Séguéla	1.50	18.0	New
Sassandra	Daloa	0.17	2.8	New
Agnéby	Kassiguié	0.16	3.6	New

Source: CI-ENERGIES,[18] EDF[19]

RENEWABLE ENERGY POLICY

During the period 2013–2030, as part of the Strategic Development Plan 2011–2030, the Government aims to increase the share of renewable energy in the country's energy mix. In addition, Côte d'Ivoire committed itself to the Paris Agreement to reduce its greenhouse gas emissions. This commitment is reflected at the level of the electricity sector, by increasing the share of renewable energy in the energy mix to 42 per cent (including large hydropower) by 2030. This renewable energy policy will support the following renewable sources: biomass, hydropower, solar power and, possibly, wind power.

Several projects for electricity generation from renewable energy sources are planned, including: a solar power project of 25 MW in Korhogo; a Canadian solar power project (Galilea) of 50 MW in Korhogo; a solar PV project of 25 MW in Odienné; a solar power project of 25 MW developed by Bio-Therm Energy in Ferkéssedougou; a cocoa biomass power plant of 25 MW in Gagnoa; and a cotton biomass power plant of 20 MW in Boundiali.[21,18,22]

At the end of 2019, the country adopted a Sector Policy Document for the Development of Renewable Energies and Energy Efficiency (PSDEREE) with the vision of making Côte d'Ivoire a leading country in the field of renewable energy, optimal use of energy in all its forms, in order to contribute to the country's energy security and the protection of the environment in 2030.[23] This document has set the objectives of Côte d'Ivoire in terms of renewable energy and energy efficiency for the period 2020-2030. The specific objectives in terms of renewable energy are as follows:

- To promote the development of green electricity production infrastructure connected to the interconnected grid so as to increase the share of renewable energy in the electricity mix to 42 per cent in 2030, including large hydropower;
- To promote the development of green electricity production infrastructure not connected to the interconnected grid in order to accelerate the electrification of camps and isolated sites;
- To increase access to electricity for rural populations through off-grid electrification and to promote renewable energy for other uses, in particular domestic and commercial applications;
- To increase the production and use of fuels from renewable sources other than wood (briquettes, biogas, biofuels, etc.) as well as to promote modern technologies for charcoal production;
- To increase the use by households, hotels, health centres and school canteens of modern cooking systems and solar water heaters;
- To increase access to energy services for farmers through the use of renewable energy in production systems, including irrigation (solar pumping), units for processing and preserving agricultural products, pasteurization, fish farming, etc.;
- To reduce greenhouse gas emissions through the promotion of renewable energy.

There is no specific legislation or regulation for SHP. Data on costs of SHP development are not available. In addition, no financial mechanism is put in place for the development of SHP projects.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Increased variability in rainfall and shifting rainy seasons will require attention if the SHP sector is to adapt to climate change in the future. Rising temperatures are also of concern, and consequences for the sector due to temperature change should be a topic of further attention.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

There are multiple barriers to SHP development in Côte d'Ivoire. Some of the most significant ones are outlined below:

- The lack of new studies on potential sites; new studies could confirm a potential significantly greater than the current estimation of 40.685 MW;
- The main focus is on larger hydropower projects rather than on plants with capacity of up to 10 MW;
- Limited data available in the sector and restriction of information might considerably deter foreign investment.

However, due to the importance of the electricity sector for the country's economic recovery, more attention is being paid to the potential of renewable energy and it is likely that SHP will also benefit from this.[11]

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

- The political will to accelerate the transition to renewable energy sources including SHP in order to improve the electricity mix, which is predominantly fossil-based (natural gas) at the moment;
- The political will to electrify all the localities of the country by 2025. Although the preferred option is the connection by extension of the electricity grid, the development of local potentials so as to allow a better penetration of renewable sources including SHP, is recommended;
- The country is currently benefiting from technical assistance from the European Union to carry out the necessary studies to enable the development of the potential of renewable energy sources, including SHP.

REFERENCES

1. World Bank (2019). *Population, total: Cote d'Ivoire*. World Population Prospects: 2019 Revision. Available at https://data.worldbank.org/indicator/SP.POP.TOTL?locations=CI (Accessed 19 January 2021).
2. World Bank Group (n.d.). *Climate Change Knowledge Portal: Cote d'Ivoire*. Available at https://climateknowledgeportal.worldbank.org/country/cote-divoire/climate-data-historical (Accessed 11 April 2021).
3. Cote d'Ivoire National Office of Tourism (n.d.). *La Cote d'Ivoire presentation*. Available at https://civ.abidjan.net/geographie (Accessed 19 January 2021).
4. World Bank (2018). *Côte d'Ivoire Economic Update: So Tomorrow Never Dies - Key Messages*. Available at https://www.worldbank.org/en/country/cotedivoire/publication/cote-d-ivoire-economic-update-so-tomorrow-never-dies-key-messages (Accessed 19 January 2021).
5. President of Cote d'Ivoire website (n.d.). *Climat de la Côte d'Ivoire*. Available at http://www.presidence.ci/presentation-detail/102/le-climat-de-la-cote-d-ivoire (Accessed 20 March 2021).
6. Pratika Foundation et al. (2009). *Final report of the feasibility study of manual drilling - Identification of potentially favorable zones: Cote d'Ivoire*. Report not available online.
7. United Nations Development Programme (UNDP) (2012). *Final Report of the Investment Program for Access to Energy Services in Ivory Coast (PNIASE-CI)*. Available at https://www.ci.undp.org/content/cote_divoire/fr/home/library/environment_energy/publication_1.html (Accessed 19 January 2021).
8. Ivorian Electricity Company (CIE) (2019). *Annual Statistics Report & Annual Technical Minutes*. Internal documents.
9. Prime Minister's Office (2020). *Government social program 2019-2020 Report*. Available at https://psgouv.ci/assets/fichiers/Bilan_PSGouv_2019_version_imprimee.pdf (Accessed 11 April 2021).
10. Prime Minister's Office (2020). *Government social program 2019-2020 - context and rationale*. Available at https://psgouv.ci/welcome/details_presentation/contexte-et-justification509 (Accessed 11 April 2021).
11. National Authority for the Regulation of the Electricity sector (ANARE) (2016). *Decree No. 2016-785 of 12 October 2016 relating to the organization and operation of the National Regulatory Authority for the Electricity Sector of Côte d'Ivoire (ANARE-CI)*. Available at http://anare.ci/assets/files/pdf/loi_reglement/decret/Decret_n_2016-785_du_12_octobre_2016_relatif_a_l_organisation_et_au_fonctionnement_de_l_ANARE-CI.pdf (Accessed 12 April 2021).
12. National Authority for the Regulation of the Electricity sector (ANARE) (2019). *Inter-ministerial Order No. 002 / MPEER/ MEF/SEPMBPE/of January 2nd, 2019 amending the electricity tariffs*. Available at http://anare.ci/assets/files/pdf/loi_reglement/arrete/ARRETE_INTER_N002_DU_02_JAN_2019.pdf (Accessed 12 April 2021).
13. Système d'Informations Environnementales sur les Ressources en Eaux et leur Modélisation (SIEREM) (n.d.) *BARRAGE GRAH FAYE (LMNG)*. Available at http://www.hydrosciences.fr/sierem/consultation/station.asp?STID=1098501055 (Accessed 11 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. Ivorian Electricity Company (CIE) (2017). *Annual Statistics Report 2017 & Annual Technical Minutes*. Internal document.
18. Société des Energies de Côte d'Ivoire (CI-ENERGIES) (2017). *Electrical statistics*. Not available online.
19. Electricité de France (EDF) (1979). Inventory of the Republic of Côte d'Ivoire hydroelectric resources (Volume 1). September 1979. Inventory not available online.
20. Ivorian Electricity Company (CIE) (2015). *Electricity Programme for All/ Programme Electricite Pour Tous (PEPT)*. Available at http://www.cie.ci/pept/ (Accessed 11 April 2021).
21. General Directorate of Energy (2017). *Annual Activity Report 2017*. Report not available online.
22. Regions of Climate Action (2016). *Ivory Coast Solar - 25 MW*. Available at https://regions20.org/wp-content/uploads/2016/10/100-SolutionClimateProject-RE_085.pdf (Accessed 11 April 2021).
23. General Directorate of Energy (2019). *Sector Policy Document for the Development of Renewable Energies and Energy Efficiency 2020-2030 (PSDEREE)*. Document not available online.

Republic of the Gambia

Annabel Johnstone, Kaboni

KEY FACTS

Population	2,347,706 (2020)[1]
Area	11,300 km^2 [2]
Topography	The topography of Gambia is flat and largely defined by the drainage basin of the Gambia River. The highest point is in the east of the country, at Red Rock, at 53 metres above sea level. The land elevation gradually decreases from the east to the west, with the capital city of Banjul situated below 5 metres above sea level at the mouth of the Gambia River. Shallow valleys characterize the banks of the Gambia River, which cuts through the plateau across the country.[3,4]
Climate	Gambia has a wet-and-dry tropical climate characterized by an intense rainy season occurring generally between June and October, followed by a longer dry season. The east of the country experiences a hotter and drier climate (temperatures in the high 20s °C), with the climate becoming cooler and drier in the west by the coast (temperatures in the low 20s °C). The relative humidity is high but drops from December to April, when the dry north-eastern wind known as the Harmattan is dominant.[5]
Climate Change	Gambia is highly vulnerable to rainfall variations caused by climate change, which disrupt the agricultural workers' (44 per cent of the population) traditional knowledge of the historic patterns of rainfall and optimal harvest times. Climate change impacts, such as increasing temperatures, droughts, a shifting rainy season with decreased intensity as well as increased deforestation, have resulted in half the available land in Gambia becoming degraded through topsoil and secondary sediment erosion. According to the Climate Change Knowledge Portal, mean annual temperatures are expected to rise by between 1.1 and 3.1 °C by 2060, and between 1.8 and 5 °C by 2090 .[6,7,8]
Rain Pattern	The rainy season lasts longer and is heavier by the coast, while rainfall intensity diminishes eastwards. At the town of Yundum (west), the average annual rainfall averages 1,300 mm, while at the town of Basse Santa Su, approximately 435 km inland, it averages 1,000 mm. August is the rainiest month, when rainfall exceeds 300 mm in the city of Banjul.[4,5]
Hydrology	Gambia is dominated by the Gambia River, a major river of Western Africa. The river, 470 km long, and its tributaries occupy 970 km^2 of permanent surface water area. Total renewable water resource in Gambia is constant at $8x10^9$ m^3 per year, of which approximately 62 per cent flows into Gambia from neighbouring countries. The total head of the Gambia River in Gambia is 10 metres. A combination of increased temperatures and reduced rainfall from climate change is expected to decrease annual streamflow by 22 per cent by 2050, according to a global warming scenario of 3.5 °C by the year 2100.[9,10]

ELECTRICITY SECTOR OVERVIEW

The electricity sector in Gambia is predominantly non-renewable, with only 3 MW of the 105 MW of installed capacity as of 2019 coming from renewable sources (2 MW of solar power and 1 MW of wind power) (Figure 1). Similarly, most new capacity added over the last decade comes from non-renewable sources: 11 MW from non-renewable sources compared to 2 MW from solar power.[11]

Gambia does not import or export electricity. However, projects from the World Bank, United Nations Environment Programme (UNEP) and the Economic Community of West African States (ECOWAS) have proposed the development of the Soma hydropower plant in neighbouring Senegal as a shared project, which would represent a supply increase for Gambia to approximately 250 MW.[12,13]

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

Source: IRENA[11]

Total electricity generation reached 342.6 GWh in 2019, 336.1 GWh of which came from fossil fuel sources, with only 6.5 GWh of electricity generated from solar power and no recorded wind generation (Figure 2).[14]

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

Source: Africa Energy Portal[14]

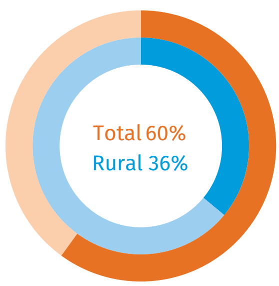
Until 2007, the country's electricity sector was controlled by the National Water and Electric Company (NAWEC), a vertically integrated monopoly under the supervision of the Ministry of Petroleum and Energy. In 2007, the Global Electric Group (GEG) was contracted by NAWEC to build, own, operate and maintain one of the two heavy fuel oil power generation facilities in the greater Banjul area in Brikama Kabafita, known as the Brikama power plant. This nearly doubled the available capacity in the country from approximately 31 MW to 55 MW. The GEG now jointly handles operations with NAWEC. Although this agreement set the precedent for the use of the independent power producer (IPP) structure in Gambia, no new electricity generation capacity has been added since, despite interest from other potential IPPs. Organisations responsible for encouraging investment in the country are the Renewable Energy Association of the Gambia (REAGAM) and the Gambia Investment and Export Promotion Agency (GIEPA).[15]

Special attention can be paid to REAGAM, a non-profit cooperation of approximately 17–19 private and public companies and individuals active in the promotion of renewable energy projects in the country, such as small solar photovoltaic (PV) installations, solar thermal power and micro-hydropower.

Despite the current low share of renewable sources in its energy mix, Gambia has a target to achieve a 100 per cent renewable energy mix by 2050, with 20 per cent of electricity coming from renewable sources by 2030. [11]

In 2018, 60 per cent of the total population had access to electricity, including 76 per cent of urban residents and 36 per cent of rural residents (Figure 3).[14]

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



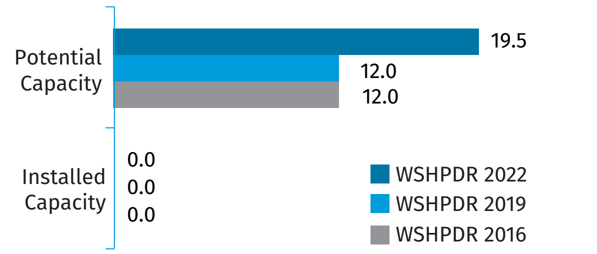
Source: Africa Energy Portal[14]

The regulation of electricity tariffs is the key role of the Public Utilities Regulatory Authority (PURA), alongside monitoring and enforcing standards of performance by public utilities and protecting the interests of the consumers. Electricity tariffs are regulated at 0.26 USD/kWh for the highest domestic consumption band and remain vulnerable to oil prices and foreign exchange shocks.[15] A lifeline tariff is offered for low-income households for the first 40 kWh consumed at a subsidized rate of 0.07 USD/kWh.[15]

SMALL HYDROPOWER SECTOR OVERVIEW

Small hydropower (SHP) is defined as hydropower plants with a capacity of up to 30 MW. For the purposes of this chapter, SHP will refer to hydropower plants with an installed capacity of up to 10 MW. Compared to the World Small Hydropower Development Report (WSHPDR) 2019, the SHP sector of Gambia has not seen any development. The estimate of technical potential for SHP up to 10 MW increased by 7.5 MW, to 19.5 MW, due to access to more accurate data (Figure 4).

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



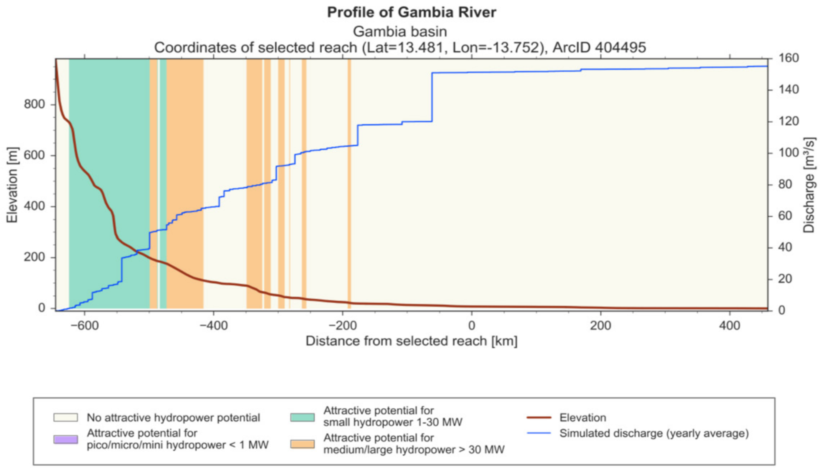
Source: *WSHPDR 2016*,[16] *WSHPDR 2019*,[17] Korkovelos et al. 2018[18]

Note: Data for SHP up to 10 MW.

There are currently no active or planned hydropower plants in Gambia, although there is a planned Western African project under ECOWAS supervision with implications for Gambia. The project envisions that two new hydropower plants located in close proximity to one another will be connected to a new regional network. The plant at Kaléta (240 MW) along with the Souapiti hydropower plant (450 MW) in Guinea will be connected to the mining region of Boké, Sénégal, Guinea Bissau and Gambia through the OMVG (the Gambia River Development Organization) line and to Côte d'Ivoire, Liberia and Sierra Leone through the CLSG (Côte d'Ivoire, Liberia, Sierra Leone and Guinea) line. The Sambangalou plant (128 MW) in Senegal will further connect to the capital of Gambia, Banjul.[19,20]

The lack of activity in SHP development in Gambia can be explained by the limited hydropower potential. In 2017, Pöyry in conjunction with ECOWAS and the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) undertook a project of mapping SHP development potential in 14 Western-African countries.[21] The report found that Gambia was well suited for SHP development, with the theoretical

Figure 5. **The Level of Attractiveness of Small Hydropower in Gambia by Elevation (m) and Discharge (m³/s)**



Source: ECREEE[14]

hydropower potential for the Gambia River estimated at 10 MW (reference period 1998–2014), whereas the estimated potential of other small streams is negligible. Therefore, all of the identified potential hydropower sites in Gambia are suitable for SHP development.[22]

The attractiveness of any hydropower projects on the Gambia River drops off at the elevation of 25 metres (Figure 5) and as mentioned previously, the entire hydrology system in Gambia has a maximum head of only 10 metres.[14]
A separate study conducted in 2018 found only one potential mini-hydropower site (0.1–1 MW) with 0.5 MW of potential capacity and three potential SHP sites (1.01–10 MW) totalling 19 MW. However, the locations of these sites are unknown.[20] Therefore, the known technical potential of SHP in Gambia is 19.5 MW, coming from four sites.

RENEWABLE ENERGY POLICY

The passing of the Renewable Energy Act in 2013 was a major step forward for Gambia in terms of the promotion of renewable energy. The Act defines a number of functions for the Ministry of Energy, including:

- Recommending national renewable energy targets;
- Determining equipment eligible for tax exemption;
- Preparing and co-ordinating the permitting process for facilities using renewable energy sources;
- Promoting the implementation of educational programmes within the renewable energy sector;
- Encouraging the development of technical and standard requirements and certification of renewable energy plants; and
- Establishing and managing a registry to monitor renewable energy facilities.[23]

The Act also defines a number of functions for PURA, including:

- Managing the Renewable Energy Fund;
- Maintaining a register of installers of systems using renewable energy resources; and
- Requiring importers of systems using renewable energy resources to provide details of compliance with internationally recognized performance and safety standards.

The Act establishes the Renewable Energy Fund and defines its funding sources, activities to be funded and management structure. The Act allows for feed-in tariffs (FITs) for on-grid renewable electricity projects with a capacity up to 1.5 MW. The maximum national capacity limit for electricity production eligible under the Act is to be published in the Feed-in Tariff Rules. The Act also provides clarification about off-grid tariffs. Renewable energy or hybrid off-grid plants of no greater than 200 kW are allowed to charge electricity tariffs to end consumers up to the current national retail tariff rates. For systems of greater than 200 kW and if the power plant developer wants to charge above the national retail tariff rate, developers must justify the tariff to the PURA as per the Electricity Act.[26]

However, certain gaps exist in the Act, which, if addressed, would provide key information for potential renewable energy development. These gaps consist of, but are not limited to:

- Provision of FITs for on-grid renewable energy plants of more than 1.5 MW;
- Provision of tariffs for off-grid renewable energy plants of more than 200 kW;
- Technical and standard requirements and certification of renewable energy plants.

There is no specific mention of SHP in the Renewable Energy Act, apart from as part of hybrid power plants. As such, the process for SHP projects should not be determined as different to the licence pathways for other renewable generation projects, which was streamlined under the Act. Instead, the Act specifically mentions biomass as a main strategy towards electrification.

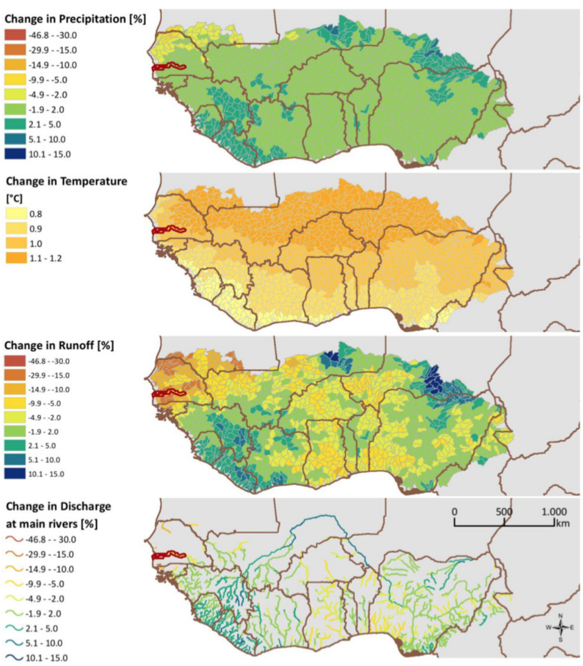
FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

Grid-connected SHP would be eligible for partial financing in the Nationally Appropriate Mitigation Action (NAMA) report of the Renewable Energy Fund set up in 2013, as well as VAT exemptions on electricity produced. There are also opportunities to attain grant financing from ECOWAS, though the pathways are unclear. The World Bank has an ongoing project to restore and modernize the electricity system in Gambia, though references in the concept note to hydropower are uncommon and more emphasis is put on solar power projects for off-grid and rural electrification.[25] The project was approved in 2018 and received additional financing in 2020.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Climate change may have considerable impact on future water resources and therefore hydropower generation. Figure 6 shows an assessment of climate change projections for Western Africa based on 15 regional climate models of the CORDEX-Africa ensembles. Two Representative Concentration Pathways (RCP4.5 and RCP8.5) were considered.[22] Whilst these changes have direct impacts on technical specifications of SHP, they will also have indirect impacts on the national tariff, reduction in agricultural revenue and an increase in flooding emergency if no immediate mitigation measures are taken.

Figure 7. **Change in Precipitation, Temperature, Runoff and Discharge in Western Africa under RCP4.5 and RCP8.5**



Source: ECREEE[21]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The electricity sector of Gambia is characterized by a number of enablers which provide opportunities for the realization of the goal of universal access to electricity. The strengths of the power sector, which could foster SHP development include the following:

- The Government's strong commitment to expand the electricity network to many communities in the country;
- Willingness of the private sector (investors) to partner with the Government to provide electricity services;
- Examples of connectivity within the subregion to learn from;
- Availability of financing through the FIT scheme;
- Available information on potential SHP sites for future development;
- Presence of a market (domestic and commercial) for the electricity that could be produced in future.

The electricity sector also faces several challenges in achieving the stated goal of ensuring wider access to electricity in Gambia, which complicates SHP development in the country. The sector barriers include the following:

- Inadequacy of the transmission and distribution network, creating incompatibility for large-scale public-private partnerships;
- Operational inefficiencies in the key utility company NAWEC resulting in transmission and distribution losses;
- NAWEC's poor financial performance;
- Weak regulatory and enforcement capacity;
- High electricity tariffs and non-affordability of electricity;
- Limited SHP potential in the country.[15,26]

These challenges combined with the low availability of commercially attractive sites will make any new development of SHP in Gambia challenging. The most viable area to focus on with SHP is the Gambia River and its estuaries in the centre of the country, near the village of Tendaba.

REFERENCES

1. The World Bank (2020). *The Gambia*. Available at https://data.worldbank.org/country/gambia (Accessed 25 February 2021).
2. World Atlas (2020). *Maps of The Gambia.* Available at https://www.worldatlas.com/maps/gambia (Accessed 25 February 2021).
3. EROS (2021). *Ecoregion and Topography of The Gambia.* Available at https://eros.usgs.gov/westafrica/ecoregions-and-topography/ecoregion-and-topography-gambia (Accessed 25 February 2021).
4. Gailey, H.A., Clark, A & Forde, E.R.A. (2020). *The Gambia.* Encyclopaedia Britannica. Available at https://www.britannica.com/place/The-Gambia (Accessed 25 February 2021).

5. Climates to Travel (n.d.). *Climate - Gambia.* Available at https://www.climatestotravel.com/climate/gambia (Accessed 25 February 2021).
6. World Bank Climate Change Portal (2021). *The Gambia.* Available at https://climateknowledgeportal.worldbank.org/country/gambia (Accessed 25 February 2021).
7. United Nations Environment Programme (UNEP) (2021). *Weathering the uncertainties of climate change in The Gambia.* Available at https://www.un.org/africarenewal/news/weathering-uncertainties-climate-change-gambia (Accessed 25 February 2021).
8. Gomez, B.E. (2006). *Climate Change Priority Action Plan (CCPAP) of Gambia*. IFCCC, 2006. Available at https://unfccc.int/sites/default/files/200609_gambia_health.pdf (Accessed 25 February 2021).
9. Food and Agriculture Organization (FAO) (2017). *Gambia, Water resources.* Available at http://www.fao.org/aquastat/statistics/query/results.html (Accessed 25 February 2021).
10. Bodian, A., Dezetter, A., Diop L., Deme, A., Djaman, A. & Diop, A. (2018). Future Climate Change Impacts on Stream flows of Two Main West Africa River Basins: Senegal and Gambia. *Hydrology,* 5(1), 21. https://doi.org/10.3390/hydrology5010021 (Accessed 02 April 2021).
11. International Renewable Energy Agency (IRENA) (2020). *Energy Profile: Gambia.* Available at https://www.irena.org/IRENADocuments/Statistical_Profiles/Africa/Gambia_Africa_RE_SP.pdf (Accessed 25 February 2021).
12. Mamos Media (2020). *Gambia: New hydro-electricity project to double generation capacity.* Available at https://www.mamostv.tv/gambia-new-hydro-electricity-project-to-double-generation-capacity/ (Accessed 02 April 2021).
13. The World Bank (2020). *Electricity Trade to Unlock Affordable and Reliable Electricity in West Africa.* Available at https://www.worldbank.org/en/news/press-release/2020/07/28/electricity-trade-to-unlock-affordable-and-reliable-electricity-in-west-africa (Accessed 02 April 2021).
14. Africa Energy Portal (2019). *Gambia*. Available at https://africa-energy-portal.org/country/gambia (Accessed 25 February 2021).
15. Sustainable Energy for All (2012). *Rapid Assessment Gap Analysis: Gambia.* Available at https://www.seforall.org/sites/default/files/Gambia_RAGA_EN_Released.pdf (Accessed 25 February 2021).
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 (Accessed 02 April 2021).
19. Aljounaidi, L., Nin, W., Taliby Sylla, C., Condé, M., Kaba, M., Chevet, H. & Dordé, F. (2018). *Kaléta and Souapiti Hydropower Schemes, a success story in Public Private Partnerships.* Available at https://www.parisinfrastructureadvisory.com/post/kale-ta-and-souapiti-hydropower-schemes-a-success-story-in-public-private-partnerships (Accessed 02 April 2021).
20. The Point (2014). *OMVG's Sambangalou project – what you need to know.* Available at https://thepoint.gm/africa/gambia/article/omvgs-sambangalou-project-what-you-need-to-know (Accessed 02 April 2021).
21. ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) (2017). *GIS Hydropower Resource Mapping and Climate Change Scenarios for the ECOWAS region, Country Report for The Gambia* (Accessed 25 February 2021). http://www.ecowrex.org/system/files/country_report_04_gambia.pdf (Accessed 1 March 2021).
22. Waterpower and Construction (2017). *Small hydro mapped out in West Africa.* Available at https://www.waterpower-magazine.com/news/newssmall-hydro-mapped-out-in-west-africa-5842789 (Accessed 25 February 2021).
23. Ministry of Energy, Republic of The Gambia (2013). *Renewable Energy Act.* Available at http://extwprlegs1.fao.org/docs/pdf/gam134879.pdf (Accessed 25 February 2021).
24. United Nations Development Programme (UNDP) (2017). *NAMA design document for rural electrification with renewable energy in The Gambia.* Available at https://www.undp.org/content/undp/en/home/librarypage/environment-energy/mdg-carbon/NAMAs/rural-electrification-with-renewable-energy-in-the-gambia.html (Accessed 25 February 2021).
25. The World Bank (2021). *Gambia Electricity Restoration and Modernization Project*. Available at https://projects.worldbank.org/en/projects-operations/document-detail/P163568?type=projects (Accessed 25 February 2021).
26. Tourray, P. (2013). *The Gambia Feed-in Tariff Implementation.* Available at https://pubs.naruc.org/pub.cfm?id=538F0D52-2354-D714-517A-00840C240BB6 (Accessed 25 February 2021).

Ghana

Chinedum Ibegbulam, Renewable Energy and Development Practitioner

KEY FACTS

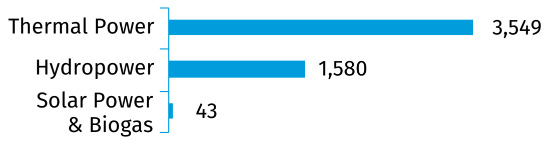
Population	31,498,920 (2022)[1]
Area	238,540 km^2 [2]
Topography	The physical terrain of Ghana is primarily represented by low plains, with several uplands and a major plateau in the south-central region. The country's highest point is Mount Afadjato at 885 metres above sea level.[3]
Climate	Ghana is characterized by a tropical climate that is relatively mild for the latitude. With the exception of the north, two rainy seasons exist, which run from April to June and from September to November. There is also a harmattan season, which is characterized by dry wind blowing from the north-east from December to March. Average temperatures range between 21 °C and 32 °C. In most areas, temperatures are highest in March and lowest in August, but no temperature lower than 10 °C has ever been recorded in Ghana.[4]
Climate Change	Over the 1961–2000 observation period, a progressive rise in temperatures and a decrease in mean annual rainfall have been recorded across the country. Other observed effects of climate change include increased variability of precipitation, rising sea levels and high incidence of extreme weather conditions and disasters. In the last 30 years, the average annual temperature increased 1°C and is projected to continue to rise. Similarly, rainfall is predicted to continue to decrease.[5]
Rain Pattern	There is a significant variation of rainfall pattern throughout the country. In the south, annual precipitation averages 2,030 mm, while Axim in the south-west of the country has the heaviest rainfall. Averagely, the month of June is the wettest month with rainfall of approximately 225–250 mm.[6]
Hydrology	Most rivers and streams north of the Akuapim-Togo ranges, including Black Volta and White Volta, form part of the Volta River system. The Volta River is approximately 1,600 kilometres in length and drains an area of approximately 388,000 km^2. The Black Volta and White Volta meet at Lake Volta, which was formed as a result of the construction of the Akosombo dam. It is also the world's largest man-made lake. There are also several other smaller rivers such as Pra, Tano, Densu, Birim and Densu.[6]

ELECTRICITY SECTOR OVERVIEW

In 2019, Ghana had a total installed generation capacity of 5,172 MW (4,695 MW of available capacity), which comprised 3,549 MW (3,296 MW available) from thermal power plants, 1,580 MW (1,365 MW available) from hydropower plants and 42.6 MW (34 MW available) from solar power and biogas combined (Figure 1).[7] The electricity generation mix in Ghana has primarily relied on hydropower and thermal power sources, however, steps have been made to introduce other renewable energy technologies in order to diversify the mix. In 2019, solar power and biogas accounted for 0.8 per cent of total installed capacity, indicating an increase compared to 0.2 per cent in 2016.[8]

Electricity generation in 2019 totalled 18,189 GWh, with thermal plants contributing almost 60 per cent (10,885 GWh), hydropower plants 40 per cent (7,252 GWh) and solar power and biogas combined 0.3 per cent (52 GWh) (Figure 2).[7] An additional 127 GWh was imported into Ghana in 2019 and 1,430 GWh was exported, making the net export 1,227 GWh.[7] Ghana imports electricity from Côte d'Ivoire and exports electricity to other neighbouring countries, including Benin, Togo and Burkina Faso. The ongoing grid expansion will allow for further expansion to other neighbouring Sub-Saharan African countries.

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



Source: Energy Commission[7]

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

Source: Energy Commission[7]

The National Electrification Scheme (NES) served as the principal instrument towards providing universal access in Ghana over a 30-year period (from 1990 to 2020). Since 1990, there has been a trend of annual increase in electrification access rate of 2.6 per cent.[9] However, the set electrification target was not achieved and in 2020 the national electrification rate stood at 86 per cent, including 95 per cent in urban areas and 74 per cent in rural areas.[10]

Before the late 1990s, the electricity sector of Ghana was a vertically integrated monopoly, with the Volta River Authority (VRA) responsible for generating and transmitting electricity to every region of the country as well as its distribution in the Northern Region through its subsidiary the Northern Energy Department (NED). The electricity sector reform in the late 1990s split the VRA and provided an opportunity for independent power producers (IPP) to enter the market. Electricity generated from hydropower is controlled by the VRA and Bui Power Authority (BPA). Additionally, the VRA and IPPs are also involved in some aspects of thermal power generation. Transmission is solely controlled by Ghana Grid Company (GRIDCO), while distribution is controlled by the state-owned entities the Electricity Company of Ghana (ECG) and the Northern Electricity Distribution Company (NEDCO).[11]

The Ministry of Energy is in charge of the formation, monitoring and evaluation of polices, programmes and projects for the country's electricity sector and is also responsible for the implementation of the NES. There are two regulatory entities responsible for the electricity sector in Ghana. The Energy Commission (EC) is responsible for issuing generation licences and for formulating electricity policy and rules governing the electricity sector including a grid code. The Public Utilities Regulatory Commission (PURC) is responsible for the regulation of the electricity, gas and water sectors, which includes tariff setting.[9]

The regional stakeholders, such as the West African Power Pool (WAPP), the ECOWAS Regional Electricity Regulatory Authority (ERERA) and ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), play an important role in the improvement of energy security in the country through interstate electricity trade and supporting improved energy services. International agencies providing support to the electricity sector of Ghana, ranging from technical assistance to financing power infrastructure projects, include the World Bank Group, African Development Bank (AfDB), United States Agency for International Development (USAID), Canadian International Development Agency (CIDA), International Renewable Energy Agency (IRENA), United Nations Environment Programme (UNEP) and Global Environment Facility (GEF).[9]

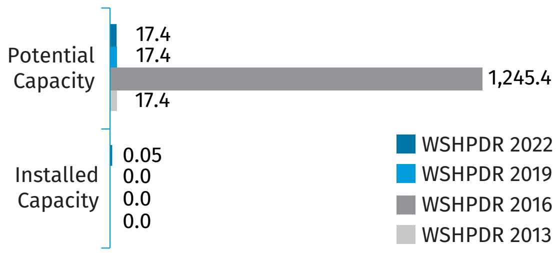
In order to sustain the real value, electricity tariffs in Ghana are adjusting based on a number of factors, such as fuel price, foreign exchange, inflation and generation mix. For low-income consumers with low consumption, PURC instituted the lifeline tariff below the cost of electricity provision.[9] Electricity tariffs are grouped into six categories based on consumer category (residential, non-residential, special load tariff and mines) and voltage level. As of January 2021, the price per kWh of electricity for residential consumers ranged from 0.33 GHS (0.04 USD) to 0.94 GHS (0.12 USD), with a monthly service charge of 7.46 GHS (0.95 USD/month) for regular consumers.[12]

SMALL HYDROPOWER SECTOR OVERVIEW

In Ghana, small hydropower (SHP) is defined as hydropower plants with capacity of up to 1 MW. Additionally, medium-scale hydropower is defined as plants with 1–10 MW capacity and large-scale hydropower as plants with 10–100 MW capacity.[13]

At present, there is one installed SHP plant in Ghana, which is the Tsatsadu power plant located in Alavanyo, Volta region. The plant was launched in 2020 and has an installed capacity of 45 kW (Table 1).[14] The SHP potential up to 10 MW is estimated to be at least 17.42 MW and approximately 9.9 MW for SHP up to 1 MW.[13] Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, installed capacity increased due to the commissioning of a new plant and potential remained unchanged (Figure 3).

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



Source: ECREEE,[13] Bui Power,[14] *WSHPDR 2013*,[15] *WSHPDR 2016*,[16] *WSHPDR 2019*[17]

Note: Data for SHP up to 10 MW.

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

Name	*Location*	*Capacity (MW)*	*Plant type*	*Operator*	*Launch year*
Tsatsadu	Alavanyo, Volta region	0.045	Run-of-river	Bui Power Authority (BPA)	2020

Source: Bui Power[14]

According to a 2012 report, the hydropower potential capacity in Ghana is 2,420 MW.[13] Various studies provide different estimates of SHP potential in different regions of the country. The Hydrological Service Department of the Ministry of Works and Housing identified approximately 15.18 MW of SHP potential from 69 sites below 2 MW. Additionally, reports by the Energy Foundation suggest that there is a potential for 2.24 MW from 12 sites less than 1 MW. Therefore, it can be assumed that the total SHP potential up to 10 MW in Ghana is at least 17.42 MW.[13] Table 2 shows a list of selected most interesting potential SHP sites identified using topographic sheets and flow data from several rivers.

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

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Plant type*	*Type of site (new/refurbished)*
Wli Falls	Afegame, Volta region	0.30	250	Run-of-river	New
Likpe Kukurantumi	Likpe Kukurantumi, Volta region	0.10–0.15	Up to 5 m by dam	Reservoir	Refurbished (construction went on for 11 months before work stopped)
Kokuma Falls	Kokuma, Brong-Ahafo	0.05	23	Run-of-river	New
Randall Falls	Kintampo, Brong-Ahafo	0.08	40	Run-of-river	New
Nworannae Falls	Asmpanaye, Western region	0.04	50–100	Run-of-river	New

Source: ECREEE[13]

RENEWABLE ENERGY POLICY

Ghana heavily depends on hydropower, mainly from the Akosombo dam, as a source for electricity generation, because hydropower provides the cheapest source of electricity compared to thermal power and other renewable energy sources. Nonetheless, the potential for alternative sources of electricity exists in the country, which includes medium-sized hydropower, mini-hydropower and other renewable energy sources, such as solar and wind power.

In 2011, the Renewable Energy Act (Act 832) was passed in order to provide a legal framework for renewable energy development.[18] The key provisions of the act included a feed-in tariff (FIT) scheme, purchase obligation and net metering. As a result, EC together with PURC developed a FIT to incentivize investment in the sector. PURC is mandated to set the FIT rates, based on which developers would be able to sign power purchase agreements (PPAs) with the distribution companies following a written approval from PURC. The Renewable Energy Act also provides for the establishment of a Renewable Energy Fund, which provides financial resources for renewable energy projects.

The Renewable Energy Master Plan (REMP) developed in 2019 offered a roadmap for long-term development of renewable energy in the country until 2030. The REMP set the following targets to be achieved:

- Increase the installed capacity of renewable energy (including hydropower up to 100 MW) to 1,363.63 MW;
- Reduce dependence on biomass;
- Provide decentralized renewable energy-based electrification options in 1,000 off-grid communities;
- Promote local content and participation in the renewable energy industry.[19]

The REMP also prescribed action plans for all renewable energy technologies. For hydropower (small- and medium-scale), the 2030 installed capacity target is set at 150 MW. According to the REMP, the Government aims to develop multiple SHP plants. The Tsatsadu plant was the first project developed under the plan. The key strategies for promoting hydropower include:

- Fast track and deploy innovative financing instruments;
- Develop a clear framework and legislation for small- and medium-scale hydropower development;
- Provide incentives, such as state-funded feasibility studies and public-private partnership arrangements;
- Collaborate with relevant stakeholders to create buffer zones, undertake reforestation and prevent mining, farming and logging activities along water ways;
- Encourage hybrid and multipurpose hydropower development (fisheries, transportation, irrigation, etc.);
- Provide capacity building for utilities, local authorities and research institutions in the installation, operation and maintenance of hydropower facilities.[19]

The Volta River Development Act 1961 (Act 46) (the VRA Act) established the oldest power entity in Ghana, the VRA. The VRA Act tasked the VRA with the responsibility to generate electricity by means of hydropower on the Volta River. In 2007, the Parliament enacted the Bui Power Authority Act 2007 (Act 740) (the Bui Power Act), which established the Bui Power Authority to oversee the development of the Bui hydropower project and any other potential hydropower sites on the Black Volta River.[20]

Under the Energy Commission Act 1997 (Act 541), participation in any segment of the electricity sector requires a licence. EC is required to make a decision on any application within a maximum period of 16 days. Reasons for denying licence issue can be founded on technical data, national security concerns, public safety or any other reasonable justification. The VRA is exempted from the requirement to apply for a licence for producing and supplying wholesale electricity from hydropower plants in the Volta River basin. Furthermore, under the Renewable Energy Act, every entity intending to engage in a commercial activity in the renewable energy sector requires a licence. To construct and operate distribution networks, an electricity distribution licence issued by EC is required. An electricity distribution licence is site-specific.[20]

In 1994, the Environmental Protection Agency Act 1994 (Act 490) was enacted in order to ensure that electricity is produced, transmitted and distributed in an environmentally sustainable manner. The act established the Environmental Protection Agency (EPA) as the principal environmental regulator in the country. Before undertaking a project, an electricity utility must receive an environmental permit from the EPA. The EPA ensures compliance with the environmental impact assessment (EIA) procedures.[20]

COST OF SMALL HYDROPOWER DEVELOPMENT

A 150 kW site at Likpe Kukurantumi with an annual output of 500–640 MWh was suggested for development. The construction cost was estimated at USD 300,000, or USD 2,000 per kW installed. The site has a head of 5 metres and, given that low-head sites are relatively more expensive to construct than high-head sites, the actual cost could be higher at approximately 3,500 USD/kW.[21]

FINANCIAL MECHANISM FOR SMALL HYDROPOWER PROJECTS

Existing financial mechanisms available for SHP projects include internally generated revenue, bilateral financing and financing from international and non-governmental organizations as well as foreign governments. The Tsatsadu SHP plant was funded largely by the Government of Ghana through BPA with financial support from the Government of Denmark and the United Nations Development Programme (UNDP).[14] An example of bilateral financing is the 400 MW Bui Dam hydropower project financed through a concessional loan of USD 270 million and a commercial loan of USD 292 million offered by China Ex-Im bank and USD 60 million in funding from the Government of Ghana.[22]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

The climate crisis poses risks to SHP development in Ghana primarily through changes in precipitation, including decreased rainfall and increased variability, and higher incidence of extreme weather conditions. A range of tailored adaptation measures based on a systematic assessment of climate risks will be required to ensure sustainable operation of SHP plants, including the physical enhancement of assets and development of appropriate strategies and policies related to, for example, emergency response and recovery.[23]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Barriers to SHP development in Ghana include:

- Lack of a regulatory and legal framework for SHP development;
- Limited funding opportunities;
- Minimal national and regional knowledge and awareness of the potential of SHP;
- Limited local expertise in developing SHP projects;
- Lack of data on water availability and flow for the development of SHP;
- Impacts of climate change on hydropower generation.[17,24]

Nonetheless, further SHP development in Ghana is possible due to the following factors:

- Political will to develop renewable energy and increase electricity access, with specific goals set for hydropower;
- Availability of undeveloped potential, with a number of suitable sites identified;
- Availability of international and regional support for renewable energy development in the country.

REFERENCES

1. Worldometer (n.d.). *Ghana population*. Available at https://www.worldometers.info/world-population/ghana-population/ (Accessed 7 June 2022).
2. World Bank (n.d.). *Surface area (sq. km) – Ghana*. Available at https://data.worldbank.org/indicator/AG.SRF.TOTL.K2?locations=GH (Accessed 7 June 2022)
3. Eros USGS (n.d.). *Ecoregions and topography of Ghana*. Available at https://eros.usgs.gov/westafrica/ecoregions-and-topography/ecoregions-and-topography-ghana (Accessed 7 June 2022).
4. Nations Encyclopedia (n.d.). *Ghana – Climate*. Available at https://www.nationsencyclopedia.com/Africa/Ghana-CLIMATE.html (Accessed 7 June 2022).
5. United Nations Development Programme (UNDP) (n.d.). *National Climate Change Adaptation Strategy*. Available at https://www.adaptation-undp.org/sites/default/files/downloads/ghana_national_climate_change_adaptation_strategy_nccas.pdf (Accessed 7 June 2022).
6. Nations Encyclopedia (n.d). *Ghana*. Available at http://www.nationsencyclopedia.com/Africa/Ghana.html (Accessed 7 June 2022).
7. Energy Commission (EC) (2019). *National Energy Statistics 2000 – 2019*. Available at http://energycom.gov.gh/

files/2020%20ENERGY%20STATISTICS-revised.pdf (Accessed 7 June 2022).
8. Sustainable Energy for All (n.d.). *Country data.* Available at https://www.se4all-africa.org/seforall-in-africa/country-data/ghana/ (Accessed 7 June 2022).
9. Kumi, E.N. (2017). *The Electricity Situation in Ghana: Challenges and Opportunities.* Centre for Global Development, Available at https://www.cgdev.org/sites/default/files/electricity-situation-ghana-challenges-and-opportunities.pdf (Accessed 7 June 2022).
10. World Bank (2020). *Access to electricity (% of population) – Ghana.* Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=GH (Accessed 7 June 2022).
11. International Trade Administration (2020). *Ghana Energy Sector.* Available at https://www.trade.gov/country-commercial-guides/ghana-energy-sector (Accessed 7 June 2022).
12. Public Utilities Regulatory Commission (PURC) (2020). *Publication of electricity tariff*. Available at https://www.purc.com.gh/attachment/642643-20210225110236.pdf (Accessed 7 June 2022).
13. ECOWAS Centre for Renewable Energy & Energy Efficiency (ECREEE) (2012). *Baseline Report on existing and potential small-scale hydropower systems in the ECOWAAS region.* Available at http://www.ecreee.org/sites/default/files/documents/basic_page/ecowas-unido_sshp_baseline_report.pdf (Accessed 7 June 2022)
14. Bui Power (2020). *President Akufo-Addo commissions Ghana's first micro hydroelectric plant.* Available at https://buipower.com/president-akufo-addo-commissions-ghanas-first-micro-hydroelectric-plant/ (Accessed 7 June 2022).
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. Parliament of the Republic of Ghana (2011). *The Eight Hundred and Thirty-Second Act of the Parliament of the Republic of Ghana Entitled Renewable Energy Act, 2011*. Available at http://energycom.gov.gh/files/RENEWABLE%20ENERGY%20ACT%202011%20(ACT%20832).pdf (Accessed 7 June 2022).
19. Ghana Ministry of Energy (2019). *Ghana Renewable Energy Master Plan.* Available at http://www.energycom.gov.gh/files/Renewable-Energy-Masterplan-February-2019.pdf (Accessed 7 June 2022).
20. Kimathi & Partners Corporate Attorneys (2018). *Electricity Regulation in Ghana*. https://www.lexology.com/library/detail.aspx?g=910beca2-f3bf-420f-8597-e7e3e6f53b38 (Accessed 7 June 2022).
21. Dernedde, S. & Ofosu-Ahenkorah, A.K (2002). *Mini Hydro Power in Ghana – prospects and challenges*. Energy Foundation. Available at https://app.sist.org.cn/label/Upload/file/Mini%20Hydro%20Power%20in%20Ghana%20-%20REPORT963925f.pdf (Accessed 7 June 2022).
22. Water technology (n.d.). *Bui Dam Hydroelectricity Project, Ghana.* Available at https://www.water-technology.net/projects/bui-dam-hydro-power-ghana/ (Accessed 7 June 2022).
23. International Energy Agency (IEA) (2020). *Climate Impacts on African Hydropower*. Available at https://iea.blob.core.windows.net/assets/4878b887-dbc3-470a-bf74-df0304d537e1/ClimateimpactsonAfricanhydropower_CORR.pdf (Accessed 7 June 2022).
24. Jonker Klunne, W. (n.d.). *Barriers to the uptake of small hydropower for rural electrification in Africa.* Available at http://proceedings.ises.org/paper/swc2011/swc2011-0054-JonkerKlunne.pdf (Accessed 7 June 2022).

Guinea

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KEY FACTS

Population	12,907,395 (2021)[1]
Area	245,857 km^2 [1]
Topography	The mid-northern region of Guinea extends from east to west in the form of a maritime plane (Lower Guinea), a region of plateaus and mountains (Middle Guinea) and the arid plateau of Upper Guinea. The south-western tip of the country, in the interior of the continent is a forested mountainous region known as Forested Guinea. It is here that the country's highest point, Mount Nimba (1,752 metres), is located. Middle Guinea surrounds the Fouta Djalon Massif, which covers an area of approximately 80,000 km^2 and culminates at Mount Loura (1,532 metres). It is mainly made up of plateaus, often more than 1,000 metres high, cut by valleys, dominating plains and depressions up to approximately 750 metres. The coastal plain of Lower Guinea is dominated to the east by the Benna Massif (1,214 metres), Mount Kakoulima (1,011 metres) and Mount Gangan (1,117 metres).[2]
Climate	The climate of Guinea is tropical or sub-equatorial depending on the area. The diversity of the terrain divides the territory into four regions with distinct climatic conditions. Lower Guinea has the longest rainy season of six months and temperatures range from 23 °C to 25 °C. Middle Guinea has shorter rainy seasons compared to Lower Guinea. In Upper Guinea, the climate is tropical and dry, with only three months of a rainy season and temperatures reaching at most 40 °C in the north-east and lows reaching 15 °C in the winter months. Forested Guinea has an equatorial climate with two separate rainy seasons interrupted by a short dry period. This region is largely humid with temperatures fluctuating between 24 °C and 28 °C for the most part of the year.[3,4]
Climate Change	According to global circulation models, annual rainfall variability and temperatures are expected to increase in Guinea under all scenarios, with some regional variation. Under a global warming scenario of 4.5 °C, the range of temperature increase in the country is expected to be between 0.4 °C and 4.8 °C by 2100. Under the 1.5 °C global warming scenario, temperatures will increase by 0.2-2.2 °C.[2]
Rain Pattern	Precipitation in the country varies by region. In the north, annual precipitation is approximately 1,200 mm per year, whereas in the south, precipitation levels can reach as high as 4,000 mm per year. Although the average in the south-east is between 1,700 and 3,000 per year. The central mountainous region of Middle Guinea has precipitation levels ranging from 1,500 to 1,300 mm per year, with the rainiest season being from April to October and the dry season from November to March.[4]
Hydrology	Nearly 1,161 water bodies in the country are fed by two mountainous massifs: the Fouta-Djallon and the Guinean Highlands (Dorsale Guinéenne). Most of the rivers have a regular flow because of the high rainfall and the very flat topography of the coastal region. However, in the part of the Lower Guinea region that borders the Fouta Djallon in its foothills, the rivers sometimes have a torrential flow due to the steepness of the slope and the rocky bottom. The most important rivers are: the Coliba, Kogon, Tinguilinta, Fatala, Konkouré, Soumba, Kolenté, and Forécariah. The prominent rivers in Middle Guinea are the Bafing and Gambia. The main rivers in Upper Guinea are the Bafing, Bakoye and the Niger basin, whose main tributaries are Mafou, Niandan, Milo, Tinkisso, Dion, Sankarani and Fié. Together they total approximately 2,500 kilometres of waterways. In addition, there are numerous large ponds and flood plains that run alongside the rivers, covering an average area of 2–4 km^2. In Forested Guinea, the main bodies of water and watercourses are made up of numerous very small ponds of less than 1 hectare in size.[2,5]

ELECTRICITY SECTOR OVERVIEW

Apart from small-scale, off-grid generation, the electricity demand of Guinea is largely met by two sources: hydropower and thermal power. Total installed capacity as of 2019 was 601.9 MW. Hydropower made up most of the installed capacity at 362.1 MW, thermal power accounted for 226.8 MW and solar power accounted for 13 MW (Figure 1).[6,7]

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

Source: EDG,[6] IRENA[7]

Note: Data only for the interconnected electricity grid (RIC).

In 2019, electricity generation in Guinea was equal to 2,040.7 GWh, of which 1,279.6 GWh came from hydropower, 21 GWh from solar and 740.1 GWh came from thermal power plants (Figure 2).[7,8] Hydropower made up 63 per cent of the on-grid generation. Of the electricity produced in 2019, the electricity company Electricité de Guinée (EDG) produced 25 per cent (496.1 GWh), while the remaining 1,483.4 GWh was produced by independent power producers (IPPs). The majority of hydropower generation is from the private Kaleta generator, which peaks in production from July to November, making up most of the country's electricity supply during these months.

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

Source: EDG,[8] IRENA[7]

Note: Data only for the interconnected electricity grid (RIC).

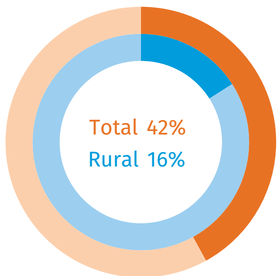
The electricity sector covers 26 urban centres in the prefectures whose electricity networks are managed and operated by EDG. EDG is charged with ensuring the provision and transport of electricity throughout the country and owns 35 per cent of the electricity market, acting as the sole buyer for many electricity producers. The Ministry of Energy (ME) (previously Ministry of Energy and Hydraulics (MEH)) oversees the electricity sector. Its organization and prerogatives were defined by Decree No. D/2016/122/PRG/SGG of 2016. Article 1 of this decree provides that the Ministry's mission is the design, development and implementation of the Government's water and energy policy. A presidential decree in 2005 established the Office of Strategy and Development of Energy (BSD), an organization charged with elaborating a strategy for the development of the energy sector. The Cellule PPP manages the public-private partnerships within the Government and acts as an interface for IPPs in the country. The country's independent power regulator, AREE (Authority for Electricity and Drinking Water Sectors), was created in 2017 by the ordinance L/2017/050/AN.

The main electricity grid, called the large interconnected grid, supplies hydropower and thermal power to Conakry, Dubréka, Coyah, Forécaréah, Kindia, Mamou, Pita, Labé and Fria. The small interconnected grid supplies the prefectures of Dabola, Dinguiraye and Faranah with electricity from the Tinkisso hydropower plant (1.6 MW). There are also the so-called isolated centres (Boffa, Gaoual, Télémelé, Lélouma, Kissidougou, Kouroussa, Boké, Kankan, Kérouané, Macenta and N'Zérékoré), which are supplied with electricity by small-scale generators (often hybrid solar with battery and diesel). A number of mini-grids are operating under concession agreements or authorizations granted by the minister in charge of energy.[9]

The country's ambition is to sell the excess of its future electricity production to neighbouring countries. In addition, Guinea is a member of several subregional organizations such as the Gambia River Basin Development Organization (OMVG) and Senegal River Basin Development Organization (OMVS), which currently work together to develop shared hydropower sites on the territory of Guinea and for the implementation of transmission lines (the Côte d'Ivoire-Liberia-Sierra Leone-Guinea (CLSG) and Guinea-Mali interconnections).[10]

Although endowed with mineral and energy resources, the electricity sector of Guinea remains poorly developed. One of the objectives of the Development of the Energy Sector Policy (Lettre de Politique de Développement du Secteur Energétique, LPDSE) of December 2012 is to increase the global electrification rate from 12 per cent in 2014 to 50 per cent by 2020.[11] While significant progress has been made since 2014, the goal for 2020 has not yet been met. As of 2019, 58 per cent of the Guinean population remained without access to electricity (Figure 3).[12] The likelihood of rural access to electricity being provided by the national grid in the medium to long term is limited, while mini-grids are a cost-effective way to fill this gap in the interim.

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



Source: World Bank[12]

The Government has developed a National Economic and Social Development Plan (PNDES) 2016–2020 that prioritizes renewable energy through decentralized solutions with the participation of the private sector.[13] The strategic purpose of the PNDES is to concretize the LPDSE as well as its Action Plan 2009–2025 to promote the development of a sustainable model based mainly on energy efficiency and renewable energy. Actions of the PNDES involve the promotion of decentralized solutions involving local authorities and the private sector at the rural level. This is in line with the Electricity Access Improvement Programme (2014) and the

Low-Cost Electrification Plan (2019). As for the electrification plans, the Government's strategy is to reach a large portion of the population with the extension of mini-grids.

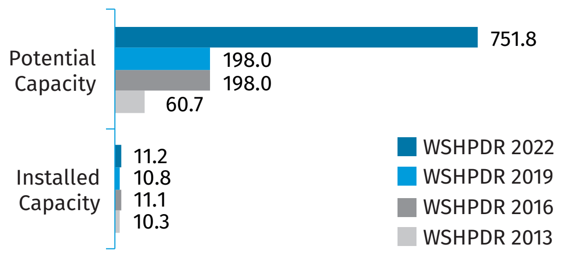
The green mini-grid programme, with support from the African Development Bank, will provide technical assistance to Guinea Agency for Rural Electrification (AGER), in the form of a help desk, for the deployment of 47 green mini-grids that have no prospect of being connected to the national grid in the next 10 years and that should allow the connection of approximately 60,000 households.[14]

The average price for electricity in 2019 was 0.064 USD/kWh (628 GNF/kWh), which indicates a 13 per cent decrease compared to average prices in 2018.[6]

SMALL HYDROPOWER SECTOR OVERVIEW

According to LPDSE, paragraph 23, micro-hydropower is defined as sites with installed capacity from 100 kW to 1,500 kW, whereas small hydropower (SHP) is not clearly defined.[15] For the purpose of this chapter, the up to 10 MW definition will be used. The total installed SHP capacity is 11.2 MW (Table 1), and has not meaningfully changed since the *World Small Hydropower Development Report (WSHPDR) 2019* (Figure 4). At the time of writing, the Banéah (5.6 MW) and Samankoun (0.24 MW) plants were undergoing renovation works, both not being connected to the central electricity grid (Table 1). Theoretical potential for hydropower plants under 10 MW amounts to 751.8 MW, revealing an increase of 280 per cent since the *WSHPDR 2019* due to new data from multiple studies.[16]

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



Source: EDG,[6] SIG,[16] *WSHPDR 2013*,[17] *WSHPDR 2016*,[18] *WSHPDR 2019*[19]

Note: Data for SHP up to 10 MW.

The French Development Agency (ADF) has agreed to co-finance four small dams: Fôkô (2.5 MW, multipurpose, Maritime Guinea), Bagata (2.2-5 MW, Middle Guinea towards Tougué), Founkeya Banko (4-5 MW, towards Dabola, Upper Guinea) and Lokoua (6-13 MW, Forest Guinea) (Table 2). These projects were undergoing technical and financial feasibility studies as of mid-2021.

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

Name	*Location*	*Capacity (MW)*	*Operator*	*Launch year*
Banéah*	Kindia	5.60	EDG	1989
Kinkon	Pita	3.44	EDG	1974
Tinkisso	Dabola	1.59	EDG	1969
Loffa	Macenta	0.16	EDG	1958
Samankoun*	Télémélé	0.39	EDG	1998 (approximate)

Source: EDG[6]

Note: *Under renovation.

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

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Developer*	*Stage of development*
Fôkô	Maritime Guinea	2.5	–	–	Feasability
Bagata	Middle Guinea	2.2-5.0	–	–	Feasability
Founkeya Banko	High Guinea	4.0-5.0	–	–	Feasability
Lokoua	Forested Guinea	6.0-13.0	–	–	Feasability
Touba	–	5.0	173	Tractebel Engineering France	Feasability

Source: SIE,[20] Tractabel Engineering[21]

One recent call for tenders in April 2021 from OMVG sought for consultants to perform feasibility studies on the Digan and Kourawel sites, with support from the African Development Bank, seeking technical, environmental and economic feasibility of the sites.[22]

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

Name	*Location*	*Potential capacity (MW)*	*Head (m)*	*Type of site (new/refurbishment)*
Daboya	Koulounkouré	2.8	37	New
Koukoutamba (Kalinko)	Bafing	6.3	15	New
Guessore	Sala	7.9	310	New
Ouességuélé	Ouességuélé river	0.9	25	New

Source: SIG[16]

The Atlas of Potential Hydropower in Guinea was put together by AECOM engineering firm, which compiled data from existing studies, such as Tractabel Engineering, and compared these findings with their own.[16] Several sites were then verified and further studied through site visits during the second stage of the process. This report identified new sites using advanced geographic modelling techniques and is the most up-to-date source for potential sites in Guinea as of mid-2021. Despite the identified vast potential of over 6,000 MW only 6 per cent of total known hydropower potential, large and small, has been developed.[16]

Several potential sites of larger capacities have encountered difficulties within the development process. The main causes of failure in hydropower development are: failure in creditworthiness in entering into a Power Purchase Agreement with EDG (as is the case with the Touba plant); change of the mining code leading to increased and complex costs (as is the case with Poudalde, 50–90 MW); and Build Operate Transfer (BOT) schemes, which encounter political problems and competing uses for the site of interest (as with the Fomi plant, 90 MW).

RENEWABLE ENERGY POLICY

The main objective, following the Energy for All initiative, is to increase the share of renewable energy sources in the country's energy mix to 30 per cent.[11] On the national policy level, the LPDSE outlined the following objectives:

- To reach a share of hydropower capacity in the grid electricity (excluding self-generation) of 70 per cent in 2017 compared to 38 per cent after the installation of 100 MW of emergency thermal power capacity in 2013;
- Develop 20 mini-hydropower plants of the inventoried 130 by 2025, including 5 by 2017, under PPP or community projects.[15]

Apart from planning, there are several concrete actions taken to further climate goals. Law L/2013/061/CNT authorizes the participation of private sector operators of plants less than or equal to 500 kW in capacity. The tariffs for the supply of electrical energy or electrical services and the conditions for their revision are established on a case-by-case basis in the specifications of the Electrification Authorizations. According to Article 30, Chapter II: Taxation of Title IV: Tariffs and Taxation, the tax regime applicable to companies holding a rural electrification permit is the most favourable regime of the Investment Code.

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

For hydropower, the main policy angle is to prioritize the development of mini- and small-scale sites with respect to large subregional schemes to meet local needs. Ministerial Order A/2013/474/MEEF/CAB of 11 March 11 2013, which adopted the general environmental assessment guide, specifies that hydropower projects below 10 MW must be subject to an impact notice, while those greater than or equal to 10 MW must be subject to a detailed environmental impact assessment (EIA).

The process for attaining a licence for SHP projects is determined when the authorization or the concession is granted by means of orders of the Minister in charge of the electricity sector, following a call for tender procedure or on the basis of unsolicited applications. Law 98/012/AN of 1 June 1988 authorizes the financing, construction, operation, maintenance and transfer of development infrastructures by the private sector using Build-Own-Operate-Transfer (BOOT) contracts.[23]

The promulgation of Law L/93/039/CTRN of 13 September 1993 on the Production, Transport and Distribution of Electricity, limits the role of the state to the definition of: the energy policy and its instruments (price and tariff system; institutional, legal and regulatory framework), the monitoring of their application and the exercise of the control of the sector. This law was enacted to ensure the quality and continuity of the public electricity service.[24]

Other pieces of legislation pertaining to the SHP sector include: Law L/2013/061/CNT of 20 September 2013, Article 9 which defines the Rural Electrification Zone (ZER), National Rural Electrification Programme (PNER), Annual Rural Electrification Programme (PAER) and the Local Rural Electrification Initiative Projects (PILER).[25]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

Some subsidies are set aside for small renewable generation under article 27, paragraph 2 of Law L/2013/061/CNT of 20 September 2013 on the rural electrification subsector. This law states that the Council for Rural Electrification must "ensure the implementation of the national policy of rural electrification as well as the proper use of resources and the optimal allocation of subsidies allocated by the Rural Electrification Fund (FER) for the development of sustainable access to electricity in rural areas, under conditions of acceptable technical, economic and financial viability, equity and transparency."[25] Financing is also available under the Programme of Decentralized Electrification (PERD) of the Office of Rural Decentralized Electrification (BERD) with co-financing from the World Bank and the Government of Guinea. This programme aims to conduct prefeasibility studies resulting in 12 locations to be selected for tendering for private investment in hybrid plants. The subsidy is estimated to amount to 60-80 per cent of initial investment costs, and has an expected closing date of December 2023.[26]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

According to studies on the effects of climate change on water systems in Guinea, water bodies will be significantly impacted up until 2100, with more significant effects seen in the second half of the century. The first national communication to the United Nations Framework Convention on Climate Change presented projection results by regions within the country on water flow reductions. Under a 1.5 °C scenario, water flow is expected to decrease by 2-8 per cent (depending on the region) by 2025 and by as much as 20-43 per cent by 2100. Under a 4.5 °C global warming scenario, regional decrease in water flow will reach between 6 and 16 per cent in 2025 and reach a reduction of between 34 and 73 per cent by 2100.[2] Several rivers have experienced negative effects due to flooding in recent years, including the Kankan (2001), Boké (2003) and Gaoual (2005).

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The following points summarize the main barriers to SHP development in Giunea that have been identified:

- Poverty of the population, especially in rural areas, and its impact on purchasing power;
- Financial barriers, such as the low national financing capacity (public and private) and subsequent high dependence on external public and private financing;
- Technological barriers including the huge technological backlog in energy industries and know-how as well as high expenses on technology and know-how transfer;
- Institutional barriers, particularly the lack of good overall governance and control of the development of the energy sector as a whole.

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

- There is a huge potential for SHP in the country and ample, available data on specific sites;
- Strong political motivation for mitigation of the negative effects of climate change;
- Interest in the country and financial aid from development institutions.

REFERENCES

1. National Institute of Statistics (2021). *Situation géographique*. Available at https://www.stat-guinee.org/ (Accessed 1 June 2021).
2. United Nations Framework Convention on Climate Change (2002). *Communication initiale de la guinee a la convention cadre des nations unies sur les changements*. Available at https://unfccc.int/sites/default/files/resource/Guinea%20INC%20French.pdf (Accessed 1 June 2021).
3. Quand Partir (n.d.). *Le climat en Guinée*. Available at https://partir.ouest-france.fr/meteo/guinee-idpays-mois-180-4.html (Accessed 1 June 2021).
4. Capaustral (n.d.) *Guinée*. Available at https://www.capaustral.com/climat-meteo-guinee.php#:~:text=La%20Guin%C3%A9e%20a%20un%20climat,par%20an%20dans%20le%20sud) (Accessed 1 June 2021).
5. Government of Guinea (n.d.). *Rapport sur la mise en œuvre du programme sur la biodiversite marine et cotiere.* Available at https://www.cbd.int/doc/world/gn/gn-nr-vmc-fr.doc (Accessed 1 June 2021).
6. Electricité de Guinée (EDG) (2019). *Annual Report 2019*. Available at https://edg.com.gn/publications/rapport-annuel-2019/ (Accessed 24 July 2021).
7. International Renewable Energy Agency (IRENA) (2021). *Country Profile – Guinea*. Available at https://www.irena.org/IRENADocuments/Statistical_Profiles/Africa/Guinea_Africa_RE_SP.pdf (Accessed 3 November 2021).
8. Personal communication from the Director of Studies and Works at Electricité de Guinée.
9. Ministry of Energy and Hydraulics (2018). *Projet d'amelioration de l'acces a l'electricite en Guinee (paaeg)*. Available at https://documents1.worldbank.org/curated/zh/376171540541289986/pdf/Rapport-CGES-PAAEG-CEMED-VF-14-10-2018-1.pdf (Accessed 2 June 2021).
10. World Bank (2017). *Project Information Document/Integrated Safeguards Data Sheer (PID/ISDS): Guinea-Mali Interconnection Project (P166042)*. Available at https://documents1.worldbank.org/curated/en/789041518474288598/text/Guinea-Mali-Interconnection-Project.txt (Accessed 2 June 2021).
11. Sustainable Energy for All (SE4ALL) (2014). *Evaluation et Analyse des Gaps par rapport aux objectifs de SE4ALL*. Available at https://www.se4all-africa.org/fileadmin/uploads/se4all/Documents/Country_RAGAs/Guinea_RAGA_FR_Released.pdf (Accessed 2 June 2021).
12. World Bank (2019). *Access to electricity – Guinea*. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=GN (Accessed 2 June 2021).
13. National Plan of Social and Economic Development (PNDES) (n.d.). *Plan National de Developpement Economique et Sociale 2016-2020*. Available at https://pndes-guinee.org/ (Accessed 2 June 2021).
14. African Development Bank Group (2020). *Guinée - Programme de développement des mini-réseaux verts en Guinée - Subvention SEFA - Rapport d'évaluation SEFA*. Available at https://www.afdb.org/en/documents/guinee-programme-de-developpement-des-mini-reseaux-verts-en-guinee-subvention-sefa-rapport-devaluation-sefa (Accessed 3 November 2021).
15. Government of Guinea (2012). *Lettre de Politique de Développement du Secteur de l'Energie (LPDSE) Energy Sector Development Policy Letter*. Available at https://www.invest.gov.gn/document/lettre-de-politique-de-developpement-du-secteur-de-l-energie (Accessed 24 July 2021).
16. Système d'Information Energétique (2015). *Atlas of Potential Hydropower in Guinea*. Available at https://www.sie-guinee-dne.org/atlas.html (Accessed 24 July 2021).
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. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
20. System d'information Energetique (n.d.). *Projets Priotitaires Priority projects*. Available at https://www.sieguinee-dne.org/informations.html (Accessed 24 July 2021).
21. Internal information provided by the author: Tractebel Engineering France (TEF) signed a contract (N°1549, 2012/514/1/6/1/2/N) in October 2012 with the Ministry of Energy and Hydraulics (MEH) of the Republic of Guinea for the realization of the feasibility studies, the preliminary design (PDD) and the elaboration of the tender documents (DAO) of four mini-hydropower plants (Daboya, Touba, Kogbédou and N'Zébéla)
22. Hydropower-dams (2021). *OMVG seeks studies for projects in Guinea and Guinea-Bissau*. Available at https://www.hydropower-dams.com/news/omvg-seeks-studies-for-projects-in-guinea-and-guinea-bissau/ (Accessed 2 June 2021).
23. Government of Guinea (2988). *Law L/98/012/AN of 1 June 1988*. Available at https://www.assemblee.gov.gn/index.php/l98012an-autorisant-la-construction-lexploitation-lentretien-et-le-transfert-dinfrastructures-de (Accessed 24 July 2021).
24. Government of Guinea (1993). *Law L/93/039/CTRN of 13 September 1993*. Available at https://rise.esmap.org/data/files/library/guinea/Documents/Renewable%20Energy/Guinea_Loi%20L_93_039_CTRN%20du%2013-9-1993_Prod_Transp_Distrib_EnEle.pdf (Accessed 24 July 2021).
25. Government of Guinea (2013). *Law L/2013/061/CNT of 20 September 2013*. Available at https://www.ecolex.org/details/legislation/loi-l2013061cnt-du-20-septembre-2013-portant-sous-secteur-de-lelectrification-rurale-lex-faoc173939/ (Accessed 24 July 2021).
26. World Bank (2019). *Guinea Electricity Access Scale Up Project (P164225)*. Available at https://documents1.worldbank.org/curated/en/869041550631657109/pdf/Guinea-Electricity-Access-Scale-Up-Project.pdf (Accessed 41 July 2021).

Liberia

International Center on Small Hydro Power (ICSHP)

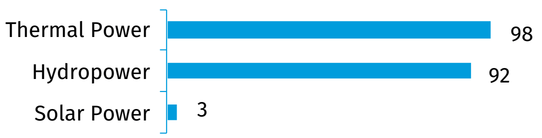
KEY FACTS

Population	5,057,677 (2020)[1]
Area	96,320 km^2 [2]
Topography	The topography of Liberia ranges from flat coastal lowlands to rolling hills and plateaus. Along the border with Guinea runs the Nimba Mountain Range and along the coastal plains are savannahs and degraded forests. The hills of the tropical forest and the montane forest zone are covered by dense rainforests. The highest point in the country, Mount Wuteve, culminates at 1,380 metres above sea level.[3]
Climate	Liberia has a warm and humid climate, especially on the coast. The rainy season lasts from May to October and the dry season from November to April. The dry and dusty desert wind from the Sahara brings relief from the high humidity. Mean annual temperatures in the country range from 18 °C in the northern highlands to 27 °C along the coast.[4]
Climate Change	The key effects of climate change observed in Liberia include droughts and increased temperatures, particularly during summer. An observed increase in heavy rainfall events, erosion and floods threaten many areas of economic and social life in the country. Between 1960 and 2006, mean annual temperature increased by 0.8 °C at an average rate of 0.18 °C per decade. This trend is projected to increase to 0.9 °C for the decades 2020-2039. The average number of hot nights has been increasing as well, with a reported increase of 57 nights. Concomitantly, the average number of cold nights has decreased by 18 days.[5]
Rain Pattern	Average annual rainfall in Liberia exceeds 2,500 mm. Rainfall is high along the coast but decreases towards the plateaus and low mountains. The southern areas receive more rainfall than the rest of the country with the area around Cape Mount receiving the most rainfall (5,200 mm).[4,6]
Hydrology	The Morro and Mano Rivers in the north-west and the Cavalla in the east and south-east of the country are the major rivers in Liberia forming sections of its borders. River traffic and short-distance navigation in most rivers are hindered by rapids, waterfalls and sandbanks that occur often in upstream sections of rivers. The Farmington River is a source of hydropower in the country.[4]

ELECTRICITY SECTOR OVERVIEW

The main sources of electricity in Liberia are hydropower and thermal power. In 2019, total electricity generation in the country amounted to 226 GWh, of which hydropower accounted for 55 per cent and thermal power for 43 per. Solar power accounted for 4 GWh, or 2 per cent, of the total generation (Figure 1).[7]

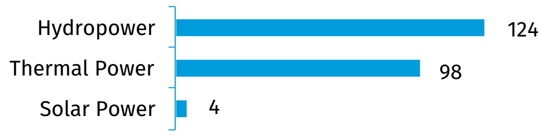
Figure 1. **Annual Electricity Generation by Source in Liberia in 2019 (GWh)**



Source: IRENA[7]

In 2020, the total installed electricity capacity in Liberia was 193 MW, of which thermal power, hydropower and solar power represented 51 per cent, 48 per cent and 1 per cent, respectively. The thermal power accounted for is non-renewable and amounts to 98 MW, whereas the hydropower capacity stands at 92 MW (Figure 2).[7]

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

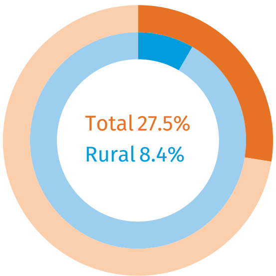


Source: IRENA[7]

In Liberia, the main electricity regulating body is the Liberia Electricity Regulatory Commission (LERC). LERC oversees the development and operation of the electricity sector well issues licences for the generation, transmission, supply and import of electricity in the country. The main utility is the state-owned Liberia Electricity Corporation (LEC), founded in 1973. The LEC is in charge of the production, transmission and supply of electricity in the country.[8]

Liberia endured a 14-year civil war that greatly affected the country's infrastructure, including completely destroying the electricity sector. As a result, the electrification rate is one of the lowest in the world. In 2020, less than 28 per cent of the total population had access to electricity, with an 8 per cent access rate in rural areas (Figure 3).[9,10]

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



Source: World Bank[9,10]

Considerable efforts have been undertaken by the Government of Liberia, international development partners and the LEC to rebuild and develop the electricity sector following the devastating damage from the civil war and post-war looting. Part of this effort was to construct addition transmission lines within the country. The Liberia Interconnected Transmission System operates at 66 kV and spans 128.7 kilometres and is expected to increase to over 248 kilometres upon completion of the ongoing transmission expansion projects. Some of these projects are the European Union–funded Monrovia Consolidation Project, the World Bank–funded Liberia Accelerated Electricity Expansion Project, the KfW Bank-funded Electrification and Grid Upgrade Project and the African Development Bank (AfDB)–funded Roberts International Airport corridor project.[8]

In line with the Sustainable Energy 4 All (SEforALL) initiative and the United Nations Sustainable Development Goals (SDGs), the Government of Liberia is committed to achieving a 20 per cent rural electrification rate as well as a total electrification of all county capitals, healthcare facilities and secondary schools by 2025. Under these initiatives, no country is to have an electrification rate below 15 per cent by 2030.[11]

Liberia is a member country of the Economic Community of West African States (ECOWAS). The ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) aims to support the development of renewable energy sources and energy action plans in the member states. Liberia is also part of the West African Power Pool (WAPP), a regional organization dedicated to fostering greater cooperation in the region's power sector and interconnection among countries to enhance energy security.[12]

The electricity tariffs in Liberia are some of the highest in the ECOWAS region, ranging from 0.15 USD/kWh to 0.24 USD/kWh.[8]

SMALL HYDROPOWER SECTOR OVERVIEW

The definition of small hydropower (SHP) in Liberia conforms to that of the Economic Community of West African States (ECOWAS), which is up to 30 MW. There are currently two operational SHP plants in Liberia: a 4.8 MW plant in Harbel, Margibi, operated by the rubber-producing company Firestone Plantation Company and a 60 KW plant in Yandohun, Lofa. The total installed capacity of SHP in Liberia is 4.86 MW (Table 1).[13,14]

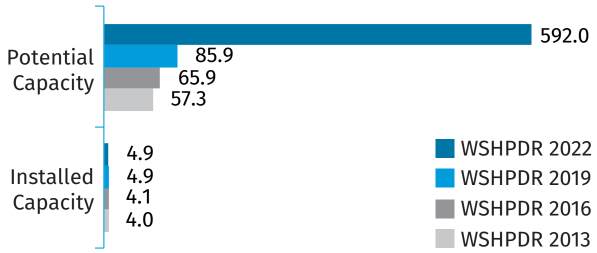
Table 1. **List of Operational Small Hydropower Plants in Liberia**

Name	*Location*	*Capacity (MW)*	*Operator*
Harbel	Margibi County	4.80	Firestone Plantation Company
Yandohun	Lofa County	0.06	Yandohun Electricity Development Cooperative

Source: Renewables Liberia[13,14]

In order to determine the SHP potential of Liberia, studies were conducted in 2015 by the European consultant company AFRY (then-Pöyry Energy GmbH) for the ECREEE. An estimated theoretical SHP potential of 592 MW was identified and published in the GIS Hydropower Resource Mapping and Climate Change Scenarios for the ECOWAS Region, Country Report for Liberia.[15] Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, estimated potential increased considerably based on data from a more recent and thorough study, whereas the installed capacity has remained unchanged (Figure 4). Table 2 shows a list of some planned SHP projects.

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



Source: ECREEE,[15] *WSHPDR 2013*,[16] *WSHPDR 2016*,[17] *WSHPDR 2019*[18]

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

Name	*Capacity (MW)*
Gbedin Falls	9.34
Kaiha	2.50
Kaiha 2	2.50

Source: Hydro Review,[19] RREA[20]

RENEWABLE ENERGY POLICY

Liberia does not have a consolidated renewable energy policy document. In 2007, the Government of Liberia drafted a Renewable Energy and Energy Efficiency Policy and Action Plan (REEEPAP) that emphasizes the importance of renewable energy and prioritizes the creation of the Rural and Renewable Energy Agency (RREA). The RREA was subsequently created in 2010 with the mission to promote the commercial development and supply of energy in rural areas in order to facilitate their economic development. The REEEPAP also recognizes the great potential for and importance of SHP development.[21,22]

In addition to the REEEPAP, in 2009 the Government of Liberia developed a National Energy Policy (NEP) with a long-term strategy to achieve carbon neutrality in energy production and transformation by the year 2050. This strategy is aligned with Liberia Rising Vision 2030, the country's development strategy for inclusive development.[21]

Liberia is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol and the Paris Agreement. In 2021, the Government of Liberia updated its Nationally Determined Contribution (NDC) and, as part of its mitigation targets, commits to developing off-grid SHP by developing several sites with 20 MW capacity by 2030. The NDC also highlights the importance of solar power and commits to installing 10 MW of solar photovoltaic (PV) plants by 2025 through partnerships with independent power producers (IPPs).[21]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

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

- The Electricity Law (2015);
- Executive Order No. 23 on the creation of the RREA (2010).

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The development of SHP in Liberia is mainly hampered by:

- The lack of a comprehensive renewable energy policy with a clear strategy for SHP development;
- Deficient electricity network due to extensive infrastructure damage from war;
- Lack of local capacity for the installation and maintenance of SHP plants;
- Limited availability of hydrological data.

Enablers for SHP development in Liberia include:

- Specific mention of the importance of SHP development in the country's NDC and REEEPAP;
- Plans to promote private sector investment in SHP as outlined in the country's NDC;
- Thorough assessment of SHP potential as outlined in the GIS Hydropower Resource Mapping and Climate Change Scenarios for the ECOWAS Region, Country Report for Liberia.

REFERENCES

1. World Bank (2020). *Population, Total – Liberia*. Available at https://data.worldbank.org/indicator/SP.POP.TOTL?locations=LR (Accessed 9 June 2022).
2. World Bank (2020). *Land Area (Sq. Km) – Liberia*. Available at https://data.worldbank.org/indicator/AG.LND.TOTL.K2?locations=LR (Accessed 9 June 2022).
3. United States Geological Survey (USGS) (n.d.). *Ecoregions and Topography of Liberia*. Available at https://eros.usgs.gov/westafrica/ecoregions-and-topography/ecoregions-and-topography-liberia#:~:text=Liberia's%20landscapes%20range%20from%20flat,stretches%20along%20the%20Guinea%20border (Accessed 9 June 2022).
4. Jones, A., Holsoe, S., Petterson, D. & Bowen, A. (2021). *Liberia*. Encyclopaedia Britannica. Available at https://www.britannica.com/place/Liberia (Accessed 9 June 2022).
5. World Bank (2021). *Climate Risk Country Profile: Liberia*. Available at https://climateknowledgeportal.worldbank.org/sites/default/files/2021-07/15917-WB_Liberia%20Country%20Profile-WEB%20%281%29.pdf (Accessed 9 June 2022).
6. Climate Change Knowledge Portal (2020). *Climatology – Liberia*. Available at https://climateknowledgeportal.worldbank.org/country/liberia/climate-data-historical (Accessed 9 June 2022).
7. International Renewable Energy Agency (IRENA) (2021). *Energy Profile: Liberia*. Available at https://www.irena.org/IRENADocuments/Statistical_Profiles/Africa/Liberia_Africa_RE_SP.pdf (Accessed 13 June 2022).
8. Liberia Electricity Regulatory Commission (LERC) (2022). *Annual Report 2021*. Available at https://lerc.gov.lr/pg_img/LERC%20Annual%20Report%202021_Final%20(1).pdf (Accessed 13 June 2022).
9. World Bank (2020). *Access to Electricity (% of Population) – Liberia*. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=LR (Accessed 13 June 2022).
10. World Bank (2020). *Access to Electricity, Rural (% of Rural Population) – Liberia*. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS?locations=LR (Accessed 13 June 2022).
11. Rural and Renewable Energy Agency (RREA) (n.d.). *Rural Electrification Access Targets*. Available at http://liberiaruralenergy.org/?q=content/rural-electrification-access-targets (Accessed 13 June 2022).
12. Abdulrahman, J. & Paco, D. (2020). *Regional Progress Report on Renewable Energy, Energy Efficiency and Energy Access in ECOWAS region Monitoring year: 2018*. ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE). Available at http://www.ecreee.org/sites/default/files/documents/regional_progress_report_2018_final.pdf (Accessed 13 June 2022).

13. Renewables Liberia (n.d.). *Yandohun Hydropower Mini-Grid*. Available at http://www.renewables-liberia.info/index.php/projects-new/project-plants/114-yandohun-hydro-power-plant (Accessed 14 June 2022).
14. Renewables Liberia (n.d.). *Firestone Plantations Hydropower Plant in Harbel, Margibi*. Available at http://www.renewables-liberia.info/index.php/projects-new/project-plants/129-firestone-plantations-hydropower-plant-in-harbel-margibi (Accessed 14 June 2022).
15. ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) (2017). *GIS Hydropower Resource Mapping and Climate Change Scenarios for the ECOWAS Region, Country Report for Liberia*. Available at http://www.ecowrex.org/sites/default/files/country_report_08_liberia.pdf (Accessed 14 June 2022).
16. 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.
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 (2019). *World Small Hydropower Development Report 2019.* United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
19. Hydro Review (2020). *AfDB and Liberia sign financing agreements for 9.34-MW small hydro power plant*. Available at https://www.hydroreview.com/hydro-industry-news/afdb-and-liberia-sign-financing-agreements-for-9-34-mw-small-hydro-power-plant/#gref (Accessed 14 June 2022).
20. Rural and Renewable Energy Agency (RREA) (2019). *Specific Procurement Notice - Request for Bids*. Available at https://rrealiberia.org/new/pg_img/SPECIFIC%20PROCUREMENT%20NOTICE-SHP%20Kaiha%202%20project%2003.08.19-Final%20Reviewed.pdf (Accessed 14 June 2022).
21. Environment Protection Agency (2021). *Liberia's Revised Nationally Determined Contribution (NDC)*. Available at https://unfccc.int/sites/default/files/NDC/2022-06/Liberia%27s%20Updated%20NDC_RL_FINAL%20%28002%29.pdf (Accessed 15 June 2022).
22. Rural and Renewable Energy Agency (RREA) (n.d.). *Overview*. Available at https://rrealiberia.org/new/page_info.php?&7d5f44532cbfc489b8db9e12e44eb820=MTQw (Accessed 15 June 2022).

Mali

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

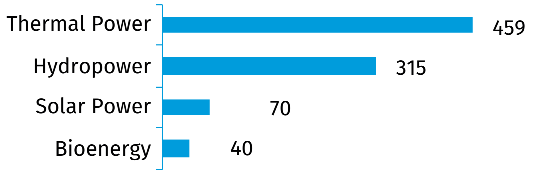
KEY FACTS

Population	20,250,834 (2020)[1]
Area	1,240,192 km^2[2]
Topography	Mali is a mostly flat country with occasional high-rising plateaux. Almost half of the country is covered by the Sahara Desert in the north. The open steppes of Akle Azaouad (AKA) plateau and the rocky terrain of Adrar-Timetrines and of Tilemsi from east to north. The southern part of the Sahara Desert in Mali transitions into the Sahel Region, interrupted in central Mali by the alluvial plains of the Inland Niger Delta. The majority of the country's agricultural land is found in southern Mali, in the plains of the Sudanian Region.[3]
Climate	Lying within the intertropical zone, Mali has a hot and dry climate as the sun nears its zenith throughout most of the year. There are two main seasons: dry and wet seasons. The dry season (November–June) is marked by high temperatures and low humidity, with daytime temperatures reaching 45 °C. The wet or rainy season (June-October) is characterized by gusty winds and heavy rainfall. Temperatures in the Sahara Desert can range from daytime extremes of 60 °C and night temperatures of 4 °C.[2]
Climate Change	Mali is affected by global warming, with mean annual temperatures having increased by 0.7 °C since 1960 at an average rate of 0.15 °C per decade. This increase is observed especially in the hot and dry season. The frequency of nights considered hot has increased considerably, except in the months of December to February. Droughts have also increased, particularly in the northern regions, and a decrease in rainfall has been observed.[4]
Rain Pattern	Mali experiences variable rainfall throughout the country, with the southern Sudanian regions receiving annual rainfall of between 510 mm and 1,400 mm and the Sahelian Region receiving between 200 mm and 510 mm. The mean annual precipitation in Mali is 322 mm.[2,4]
Hydrology	Two main rivers cut through Mali: the Senegal River and the Niger River. The Niger River, which runs through the country for over 1,600 km, flows north-east across the Mandingue Plateau and is interrupted by waterfalls and a dam at Sotuba. The Senegal River runs through Mali for 670 km and flows towards the Atlantic Ocean in a north-west direction.[2]

ELECTRICITY SECTOR OVERVIEW

The main sources of electricity in Mali are thermal power and hydropower, accounting for 61 per cent and 37 per cent, respectively, of total electricity production of 3,952 GWh in 2019. Bioenergy and solar energy contributed 67 GWh and 4 GWh, or less than 2 per cent and 0.1 per cent, respectively, of the total production that year (Figure 1).[5]

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

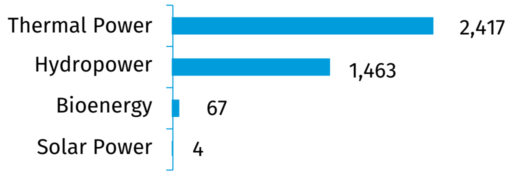


Source: IEA[5]

Most of the hydropower consumed in Mali is generated by the 200 MW Manantali hydropower plant, which also supplies most of the hydropower consumed by the neighbouring countries of Senegal and Mauritania, and by the 60 MW Felou plant shared with Senegal. Mali is also home to the largest solar plant in Western Africa: the 50 MW Kita plant. The electricity shared with neighbouring countries is part of the Synchronized Western Network, a subgroup of the West African Power Pool (WAPP) that connects four countries of the Economic Community of West African States (ECOWAS): Mali, Senegal, Niger and Burkina Faso.[5]

In 2020, Mali had 459 MW of installed thermal power capacity representing approximately 52 per cent of the total installed electricity capacity of 884 MW. Hydropower accounted for 315 MW or 36 per cent of the total installed capacity. Installed solar power and bioenergy capacities were 70 MW and 40 MW, respectively, or almost 8 per cent and 5 per cent of the total installed electricity capacity (Figure 2).[6]

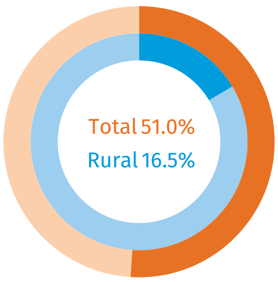
Figure 2. **Installed Electricity Capacity by Source in Mali in 2020 (MW).**



Source: IRENA[6]

In 2020, the total rate of access to electricity in Mali was 51 per cent, with the rural electrification rate being less than 17 per cent (Figure 3).[7]

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



Source: World Bank[7]

Electricity in Mali is supplied by Energie du Mali SA (EDM-SA) through three separate electric systems: the interconnected system, the isolated centres and the interconnection with the grid of Côte D'Ivoire. Until 2010, the EDM-SA was the sole entity allowed to produce, transmit, supply, commercialize and export electricity in Mali. Since 2010, the Electricity and Water Regulatory Board (CREE), which is mandated by a ministerial decree to regulate the electricity sector and clean water supply in urban centres, has been able to authorize third parties to access the national grid. Rural off-grid energy services with generation systems below 250 kW are provided by independent operators through the Malian Agency for the Development of Household Energy and Rural Electrification (AMADER).[8,9,10]

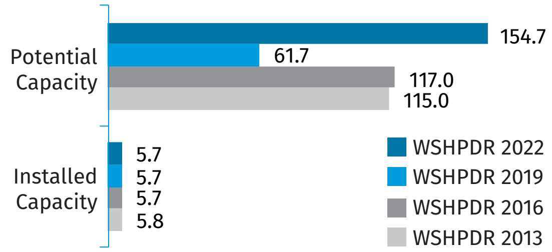
In 2001, the Government of Mali committed, through partnership, to the Sustainable Energy for All (SEforALL) with the aim of providing electricity access to at least 87 per cent of the population by 2030. In 2006, the Government debuted the National Energy Policy (PEN) to support and strengthen the energy sector and its contribution towards a sustainable economic and social development. In 2014, the Government launched the National Renewable Energy Action Plan 2013–2033 (PANER) in order to address the specific issue of renewable energy (RE).[8,11]

The electricity tariffs in Mali are subsidized by the Government and have not increased in any significant manner over the years. In 2018, the tariffs were between 0.11 USD/KWh and 0.25 USD/KWh. There are no recent tariffs published by official sources, however it can be assumed that they have not varied significantly.[12]

SMALL HYDROPOWER SECTOR OVERVIEW

In Mali, small hydropower (SHP) refers to plants with installed capacity of up to 30 MW. There is currently one operational SHP plant, the 5.7 MW run-of-river Sotuba plant. The country has an estimated SHP potential of up to 154.7 MW, a 150 per cent increase from the estimated potential in the *World Small Hydropower Development Report* (*WSHPDR*) *2019* (Figure 3). This increase is based on newer studies of various sites as included in the Renewables Readiness Assessment of Mali by the IRENA.[12]

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



Source: IRENA,[12] *WSHPDR 2013*,[13] *WSHPDR 2016*,[14] *WSHPDR 2019*[15]

In 2020, the Ministry of Energy and Water invited sealed bids for the design, commissioning, installation and supply of a 7.5 MW SHP plant in Djenné designed to supply 5,200 local households with electricity. The Djenné plant is one of the two SHP plants with a combined capacity of 8.9 MW that are being developed under the Mini-Hydropower Plants and Related Distribution Networks Development Project (PDM-Hydro), the other one being located in Talo. As of 2022, the Government was in the process of environmental and social audits in preparation for the construction of the SHP plants.[16,17]

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

Name	*Capacity (MW)*
Moussala	30.0
Taoussa	20.0
Gourbassi	13.0
Markala	10.0
Djenné	7.5
Sotuba II	6.0
Kourouba	3.9
Talo	1.4

Source: IRENA,[12] Hydropower & Dams,[16,17] GOPA-INTEC[18]

In addition to the Djenné and Talo plants, the Government launched a project to build a new 3.9 MW SHP plant on the Sankarani River. This plant, located in the Kourouba region, aims to bring electricity to approximately 20,000 people in the region. The consulting services for this project are courtesy of the German GOPA International Energy Consultants (GOPA-INTEC) and are financed by the African Development Bank (AfDB).[18]

RENEWABLE ENERGY POLICY

Concomitantly with the NEP, the Government of Mali formulated a National Strategy for the Development of Renewable Energies and, in 2008, a National Strategy for the Development of Biofuels. The objectives of these policies were to promote widespread use of RE technologies as well as creating the best conditions for the sustainability of RE services. The Latter policy emphasized the development of indigenous energy sources, which are renewable and readily available.[11] In 2011, the Climate Investment Fund (CIF) approved the Scaling up Renewable Energy Programme (SREP), which aimed to assist in the development of RE in Mali. The SREP comprised three investment projects:

- The Scatec project for the development of solar energy;
- The project to build solar photovoltaic (PV)/biofuel hybrid hydropower systems in rural areas;
- The Mini-Hydropower Plants and Related Distribution Networks Development Project (PDM-Hydro).[19]

The Scatec project has progressed with the company Scatec Solar and its partners signing an amendment with the Government of Mali, in 2019, for the production of solar energy. The project is funded by the Norwegian Agency for Development Corporation (NORAD), the International Finance Corporation (IFC) and AfDB. The funding also includes a concessional loan from the CIF of USD 20 million under the SREP. The Scatec project signed a power purchase agreement (PPA) with the EDM-SA in 2015 to build, own, operate and maintain a 33 MW solar power plant with a 51 per cent shareholding. Annual production of the plant is expected to be approximately 57 GWh.[19,20]

The PDM-Hydro project aims to enhance access to electricity in rural areas, particularly in the regional provinces of Mopti and Ségou where much of the studies were conducted. An estimated 12,500 households and economic operators are expected to be connected through the project.[19]

In 2014, the Government adopted the National Renewable Energy Action Plan 2013–2033 (PANER) and the National Energy Efficiency Plan (PANEE). The two strategies were merged in 2015 for a consolidated National Renewable Energy Action Plan (NREAP) that follows SEforALL guidelines and sets targets for 2030 including 1,416 MW of installed RE capacity.[11]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

The main legislation and regulation documents in Mali concerning hydropower projects are:

- Electricity Law No. 90-10/AN-RM (1990);
- Order No. 00-019/P-RM (2000) on the organization of the energy sector;
- Order No. 00-021/P-RM (2000) on the creation of the CREE.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Observed hydrological trends in the Niger Basin, where the Sotuba SHP plant is located, highlight a negative impact on the performance of the hydropower plant. Since 1907, a high inter-annual flow variability has been observed, culminating in a decrease in annual flow since 1970. In addition to this flow variability, a decrease in groundwater levels of tributaries to the Niger River has been observed, leading to a runoff deficit.[11]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

SHP development in Mali is mainly hampered by:

- Difficult return on investment due to high investment costs and the need for an affordable price of kWh for poor households;
- Climate change affecting performance of hydropower plants through inter-annual flow variability;
- Concerns over the pollution of rivers due to the deployment of distribution lines, which may leave construction and packaging material onsite;
- Concerns of indigenous populations over changes to their lifestyles due to construction of power plants, such as pollution from construction through deposit of building and construction material;

Enablers for SHP development in Mali include:

- Government policies that focus on RE and the importance of mini-grid projects in rural areas encourage adequate solutions such as SHP;
- International funding for SHP projects through the PDM-Hydro project;
- The prospect of job creation brought about by construction, operation and maintenance of SHP plants, which would help alleviate social issues in Mali.

REFERENCES

1. World Bank (2020). *Population, Total – Mali*. Available at https://data.worldbank.org/indicator/SP.POP.TOTL?locations=ML (Accessed 10 May 2022).
2. Encyclopaedia Britannica (2018). *Mali*. Available at http://www.britannica.com/place/Mali (Accessed 10 May 2022).
3. United States Geological Survey (n.d.). *Ecoregions and Topography of Mali*. Available at https://eros.usgs.gov/westafrica/ecoregions-and-topography/ecoregions-and-topography-mali (Accessed 10 May 2022).
4. Climate Knowledge Portal (2020). *Mali – Climatology*. Available at https://climateknowledgeportal.worldbank.

org/country/mali/climate-data-historical#:~:text=The%20 Malian%20climate%20is%20characterized,35%C2%B0C%20 in%20May. (Accessed 10 May 2022).
5. International Energy Agency (EIA) (2021). *Clean Energy Transition in the Sahel Report*. Available at https://iea.blob.core.windows.net/assets/e41015b1-4399-4635-a95a-d6769d0f319a/CleanEnergyTransitionsintheSahel.pdf (Accessed 10 May 2022).
6. International Renewable Energy Agency (IRENA) (2021). *Energy Profile – Mali*. Available at https://www.irena.org/IRENADocuments/Statistical_Profiles/Africa/Mali_Africa_RE_SP.pdf (Accessed 10 May 2022).
7. World Bank (2020). *Access to Electricity (% of Population) – Mali*. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=ML&most_recent_year_desc=true (Accessed 11 May 2022).
8. Ministry of Energy and Water (2019). *Prospectus d'Investissement de l'Energie Durable pour Tous SEforALL du Mali*. Available at https://www.se4all-africa.org/fileadmin/uploads/se4all/Documents/Country_AAs/PI_SEforALL_MALI.pdf [in French] (Accessed 11 May 2022).
9. Office of the Prime Minister (n.d.). *CREE (Commission de Regulation de, l'Electricité et de l'Eau)*. Available at https://primature.ml/cree-commission-de-regulation-de-lelectricite-et-de-leau/ [in French] (Accessed 11 May 2022).
10. ECOWAS Centre for renewable Energy and Energy efficiency (ECREEE) (n.d.). *Agence Malienne pour le Développement de l'Energie Domestique et l'Electrification Rurale - AMADER*. Available at http://www.ecreee.org/fr/node/9886 [French] (Accessed 11 May 2022).
11. Ministry of Energy and Water (2018). *Plan d'Action National d'Energies Renouvelables (PANER) du Mali*. Available at https://www.se4all-africa.org/fileadmin/uploads/se4all/Documents/Country_PANER/Mali_Plan_d_Actions_National_pour_les_Energies_Renouvelables_.pdf [iin French] (Accessed 11 May 2022).
12. International Renewable Energy Agency (IRENA) (2019). *Renewables Readiness Assessment: Mali*. Available at https://irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_RRA_Mali_2019_En.pdf (Accessed 11 May 2022).
13. UNIDO, ICSHP (2013). *World Small Hydropower Development Report 2013.* United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR
14. UNIDO, ICSHP (2016). *World Small Hydropower Development Report 2016.* United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
15. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019.* United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
16. Hydropower & Dams (2020). *Bids sought for construction of the Djenné mini hydro plant in Mali*. Available at https://www.hydropower-dams.com/news/bids-sought-for-construction-of-the-djenne-mini-hydro-plant-in-mali/ (Accessed 12 May 2022).
17. Hydropower & Dams (2021). *Mali seeks environmental audit of mini-hydro programme*. Available at https://www.hydropower-dams.com/news/mali-seeks-environmental-audit-of-mini-hydro-programme/ (Accessed 12 May 2022).
18. GOPA-International Energy Consultants (2020). *Mali - Kourouba hydropower plant*. Available at https://www.gopa-intec.de/news/mali-kourouba-hydropower-plant (Accessed 12 May 2022).
19. African Development Bank Group (AFdB) (2017). *Mini Hydropower Plants and Related Distribution Networks Development Project (PDM-Hydro)*. Available at https://www.afdb.org/fileadmin/uploads/afdb/Documents/Boards-Documents/MALI_-_MINI_HYDROPOWER_PLANTS_AND_RELATED_DISTRIBUTION_ENG.PDF (Accessed 12 May 2022).
20. Scatec (2019). *Scatec Solar Signs Project Documents for its 33 MW project in Mali*. Available at https://scatec.com/2019/05/31/scatec-solar-signs-project-documents-for-its-33-mw-project-in-mali/ (Accessed 12 May 2022).

Mauritania

International Center on Small Hydro Power (ICSHP)

KEY FACTS

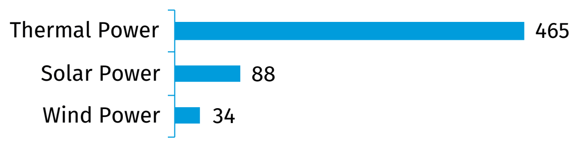
Population	4,649,660 (2020)[1]
Area	1,030,700 km^2 [2]
Topography	The country is generally flat with three geographic regions: a broad east-west band with vast plains and dunes; a narrow belt along the Senegal River to the south; and a large arid region to the north, which shades into the Sahara. Every year, the desert advances south several kilometres and brings shifting sand dunes. The highest point in the country is Mount Ijill, located near Fdérik and standing at 915 metres above sea level.[3]
Climate	Mauritania has a hot, dry and windy climate. There is sparse rainfall throughout the year for most of the territory, with the situation being worsened by the effects of rapid desertification. To the south, at the Sahelian border, the wet season is controlled by the Inter-Tropical Convergence Zone (ITCZ). The country's mean monthly temperature stays above 25 °C for most of the year, with peak temperatures of 33 °C in June and July.[4,5]
Climate Change	Mauritania is greatly affected by climate change, with the main consequences being the irregular rainfall patterns and the increasing temperatures in an already hot area. The mean annual temperature has increased by 0.9 °C since 1960 and is expected to further increase by 2-4.5 °C by 2080. The country has also been experiencing more frequent and more intensive bouts of droughts and floods, as well as a decrease in the water supply of the Senegal River. This poses a threat to the agricultural and fishing industries, which are essential for the country's economy. The global rise in sea level exposes the country to a risk of flooding of the infrastructure located on the coast. The sea level is projected to rise by 10 cm by 2030, 19 cm by 2050 and 36 cm by 2080. This risk is of particular concern to the capital and economic centre of Mauritania, Nouakchott, located on the shoreline.[5,6]
Rain Pattern	Most of Mauritania receives very little rainfall throughout the year. Annual precipitation ranges from 20 mm on the northern coast to approximately 400 mm in the central south. The southern region, at the edge of the Sahel, has a wet season between July and September with up to 200 mm of rainfall in each of those months. Changes in rainfall patterns are difficult to monitor as daily rainfall observations are limited.[5,7]
Hydrology	In Mauritania, surface water is the main water resource, of which the Senegal River and its tributaries constitute the main part. There are also considerable groundwater resources, though they are geographically disparate and play a very limited role in the country's social and economic context. Due to the country's location in a considerably arid region, there is a dependence on outside sources to meet the water demand.[8]

ELECTRICITY SECTOR OVERVIEW

The main source of electricity in Mauritania is thermal power, accounting for 863.4 GWh or almost 80 per cent of the 1,087.4 GWh generated in the country in 2020 (Figure 1). Wind and solar power accounted for approximately 11 per cent and 10 per cent of the total generation, respectively (or 115.3 GWh and 108.7 GWh).[9]

Electricity in Mauritania is owned, transmitted and distributed entirely by the Mauritanian Electricity Company (SOMELEC). There are no individual power producers in the country. SOMELEC, founded in 2001 following the demerger of the National Water and Electricity Company (SONELEC), operates in 58 cities and dozens of towns across Mauritania. The company also owns shares in the Manantali and Félou hydropower plants in neighbouring Mali.[9] In this report, the imported electricity from these plants is not accounted for in the total annual electricity generation of Mauritania, but rather in that of Mali.

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

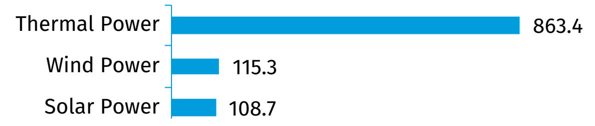


Source: SOMELEC[9]

The electricity sector of Mauritania is regulated by the Department of Electricity and Energy Management (DEME) of the Ministry of Petroleum, Energy and Mines (MPEM). DEME is in charge of both the national grid and off-grid electricity production. It regulates the work of SOMELEC and the Agency for the Development of Rural Electrification (ADER).[10]

In 2020, the total installed capacity in Mauritania was 587 MW, with the thermal power plants of SOMELEC accounting for 79 per cent (or 465 MW), the solar power farm accounting for 15 per cent (or 88 MW) and the wind farms accounting for 6 per cent (or 34 MW) (Figure 2).[11]

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

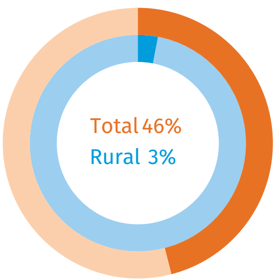


Source: IRENA[11]

As part of its Nationally Determined Contribution (NDC 2021–2030), Mauritania aims to reach a target of 13 GW of renewable energy in its energy mix by 2030.[6] The country also joined the Sustainable Energy for All (SE4ALL) initiative in 2014 and therefore adheres to the initiative's goal of doubling the share of renewable energy in the global energy mix by 2030.[12] The Government of Mauritania also aims to reach a national target rate of electrification of 70 per cent by 2030, with 95 per cent in urban areas and 40 per cent in rural areas as part of the country's Strategy for Accelerated Growth and Shared Prosperity (SCAPP) 2016–2030.[13]

As of 2020, the average price of electricity for a standardized connection in Mauritania was 0.176 USD/kWh.[14] In 2019, less than 46 per cent of the population had access to electricity, with 87 per cent in urban areas and 3 per cent in rural areas (Figure 3).[15,16,17]

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



Source: World Bank[15,16]

SMALL HYDROPOWER SECTOR OVERVIEW

There was no small hydropower (SHP) sector in Mauritania as of 2021. All existing plants in the country are large-scale and all hydropower generation is imported. The potential for SHP is unknown. However, the country is expected to have some limited SHP potential in the south, which could be exploited to provide electricity to smaller communities. This potential, however, still remains to be studied.[12]

RENEWABLE ENERGY POLICY

As part of the SCAPP, the Government of Mauritania aims to promote access to electricity in rural areas. There is, however, no official implementation plan for rural electrification policy. In 2014, the Renewable Readiness Assessment, launched by the International Renewable Energy Association (IRENA) and the United Nations Development Programme (UNDP) provided Mauritania with a study of the conditions and potential for renewable energy development. Following this assessment, the Government of Mauritania developed a high-priority renewable energy development programme for 2015–2018 as an alternative to the lacking integrated national electrification plan.[13] Since 2019, Mauritania has been part of the African Development Bank-led Desert to Power West Africa Regional Energy Programme (WAREP), which aims to provide access to electricity and enable socio-economic development in the Sahel region by harnessing the available solar power potential and adding 10 GW of solar photovoltaic generation capacity by 2025.[18]

The electricity sector of Mauritania is governed by the Electricity Code (2001–2019). The Master Plan for the Generation and Production of Electricity (2013), a long-term strategy for the development of the electricity sector in Mauritania, has been the main framework of reference for the future of the sector. However, it needs to be revised and updated to reflect the unsuccessful market liberalization strategy as SOMELEC retains monopoly of the electricity sector in the country.[13]

Due to the lack of a sufficient regulatory framework for access to sustainable energy, in 2017 Mauritania marked a relatively low score of 24 out of 100 on the World Bank Regulatory Indicators for Sustainable Energy (RISE) evaluation, placing it among the lowest scoring access-deficit countries in the world.[13]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

There is no legislation or regulations that target SHP in Mauritania. As the SHP potential is limited and there are no immediate plans for SHP development, the country's hydropower resources are all imported from Mali.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

As there are no SHP plants in Mauritania, the development of future plants is hindered by:

- The lack of sufficient data on hydropower resources

in the country;
- The lack of a comprehensive legal and regulatory framework;
- The focus of the Government's efforts on the development of other renewable energy sources with more potential, such as solar and wind power.

The known enabler for SHP development in Mauritania is:
- The SHP potential identified in the southern part of the country, which could provide some electricity to smaller communities.

REFERENCES

1. World Bank (2020). *Population, total* – Mauritania. Available at https://data.worldbank.org/indicator/SP.POP.TOTL?locations=MR (Accessed 21 January 2022).
2. World Bank (2020). *Land area (sq. km)* – Mauritania. Available at https://data.worldbank.org/indicator/AG.LND.TOTL.K2?locations=MR (Accessed 21 January 2022).
3. Nations Encyclopedia (n.d.). *Mauritania – Topography*. Available at https://www.nationsencyclopedia.com/Africa/Mauritania-TOPOGRAPHY.html (Accessed 21 January 2022).
4. World Bank (n.d.). *Country – Mauritania*. Climate Knowledge Portal. Available at https://climateknowledgeportal.worldbank.org/country/mauritania/climate-data-historical#:~:text=Mauritania%20has%20a%20dry%2C%20hot,little%20rainfall%20throughout%20the%20year. (Accessed 21 January 2022).
5. German Federal Ministry for Economic Cooperation and Development (2021). *Climate Profile – Mauritania*. Available at https://agrica.de/wp-content/uploads/2021/02/CRP_Mauritania_EN_20210208.pdf (Accessed 21 January 2022).
6. Ministry of Environment and Sustainable Development (2021). *Contribution Determinée Nationale Actualisée 2021-2030* (Updated Nationally Determined Contribution 2021-2030). Available at https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Mauritania%20First/CDN-actualis%C3%A9%202021_%20Mauritania.pdf [in French] (Accessed 21 January 2022).
7. McSweeney, C., New, M. & Lizcano, G. (n.d.). *UNDP Climate Change Country Profile – Mauritania*. United Nations Development Programme (UNDP). Available at https://www.geog.ox.ac.uk/research/climate/projects/undp-cp/UNDP_reports/Mauritania/Mauritania.lowres.report.pdf (Accessed 21 January 2022).
8. Water Action Hub (2020). *Water Risk Filter Country Profile – Mauritania*. Available at https://wateractionhub.org/geos/country/139/d/mauritania/ (Accessed 21 January 2022).
9. Société Mauritanienne d'Electricité (SOMELEC) (2021). *Présentation*. Available at https://www.somelec.mr/?q=node/1439 [in French] (Accessed 22 January 2022).
10. Ministry of Petroleum, Energy and Mines (MPEM) (n.d.). *Electricité*. Available at http://www.petrole.gov.mr/spip.php?article53 [in French] (Accessed 22 January 2022).
11. International Renewable Energy Agency (IRENA) (2021). *Energy Profile – Mauritania*. Available at https://www.irena.org/IRENADocuments/Statistical_Profiles/Africa/Mauritania_Africa_RE_SP.pdf (Accessed 22 January 2022).
12. International Renewable Energy Agency (IRENA) (2015). *Mauritania: Renewables Readiness Assessment*. Available at https://www.irena.org/-/media/Files/IRENA/RRA/Country-Report/IRENA_RRA_Mauritania_EN_2015.pdf (Accessed 22 January 2022).
13. ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) (2019). *Regional Off-Grid Electrification Project (ROGEP) – Final Report*. Available at http://www.ecreee.org/sites/default/files/ecreee_rogep_mauritania_final_report_french.pdf (Accessed 22 January 2022).
14. World Bank Group (2020). *Doing Business 2020 – Economy Profile: Mauritania*. Available at https://www.doingbusiness.org/content/dam/doingBusiness/country/m/mauritania/MRT.pdf (Accessed 4 February 2022).
15. World Bank Group (2019). *Access to Electricity (% of Population) – Mauritania*. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=MR (Accessed 10 February 2022).
16. World Bank Group (2019). *Access to Electricity, Rural (% of Population) – Mauritania*. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS?locations=MR (Accessed 10 February 2022).
17. World Bank Group (2019). *Access to Electricity, Urban (% of Population) – Mauritania*. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.UR.ZS?locations=MR (Accessed 10 February 2022).
18. African Development Bank (2021). *Project: Desert-To-Power Initiative West Africa Regional Energy Program–Phase 1*. Available at https://www.afdb.org/en/documents/multinational-desert-power-west-africa-regional-energy-program-warep-phase-1-project-appraisal-report (Accessed 10 February 2022).

Niger

International Center on Small Hydro Power (ICSHP)

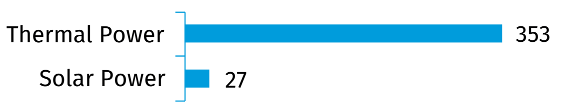
KEY FACTS

Population	24,206,636 (2020)[1]
Area	1,266,700 km^2 [2]
Topography	Niger is located in the Sahel region, a transitional zone between the Sahara Desert, which covers approximately 65 per cent of the country, and tropical Western Africa. This area is made up of shifting sand dunes, broad gravel and stony plains. Across central Niger, the pastoral areas of the Manga and Azouak regions form a wide streak of savannahs and steppes. Southern Niger is more productive, home to the Maradi-Zinder region, the largest agricultural region in the country.[3]
Climate	Niger is characterized by very high temperatures all year-round. An intense dry season from October to May is replaced by a brief, irregular rainy season brought about by the Western-African monsoon. The mean annual temperature is 27.9 °C with cooler temperatures in mountainous regions.[4]
Climate Change	Niger experiences the effects of global warming, with its mean annual temperature having increased by 0.6-0.8 °C between 1970 and 2010, higher than the global average. An increase in hotter days and nights has been observed. Rainfall has been variable from year to year and has not returned to the pre-1960s levels. The rainy seasons are shorter and harder, with an increase in extreme rainfall events and floods.[4]
Rain Pattern	With its irregular and brief rainy season, Niger enjoys relatively little rain, particularly in the northern regions, which experience 100–200 mm of rainfall. The southern regions enjoy more rain (500–600 mm), which is limited to the summer months of June–September. The mean annual precipitation is 179.6 mm.[4]
Hydrology	Niger is a dry country and has relatively poor hydrology. The main rivers in the country are: the Tapoa, Mékrou, Sirba, Dargol, Gorouol, Goroubi, Diamangou and the Niger River, the third largest river in Africa (4,200 kilometres in length, of which 500 kilometres run through Niger). Other important water bodies include Komadougou Yobé, Lake Chad and the ponds of Madarounfa, Tabalak and Guidimouni. There are important underground resources with a relatively deep groundwater level in the northern area of the country.[5]

ELECTRICITY SECTOR OVERVIEW

The main sources of electricity in Niger are thermal power and, to a much lesser extent, solar power. In 2019, the total electricity production amounted to approximately 555 GWh, of which thermal power accounted for 94 per cent, or 523 GWh, and solar power accounted for 6 per cent or 33 GWh (Figure 1).[6]

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

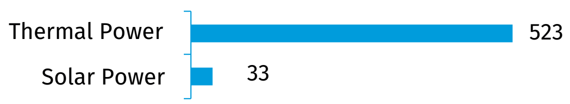


Source: IRENA[6]

The Niger Electricity Company (NIGELEC) was founded in 1968 and has a monopoly on transmission and distribution of electricity the country. In addition to the NIGELEC operations, the Coal Company of Anou Araren (SONICHAR) produces electricity from a thermal coal power plant and sells it to mining companies and has a quasi-monopoly on distribution in the cities of Agadez, Arlit and Tchirozérine.[7] The diesel and coal thermal power plants continue to play a major role in the production of electricity in the country, despite the fact that these facilities are relatively old and many have reached the age of decommissioning.[8]

In 2020, the total installed electricity capacity in Niger was 380 MW, of which thermal power represented 93 per cent. Installed solar power capacity amounted to 27 MW, or 7 per cent of total installed capacity (Figure 2).[6]

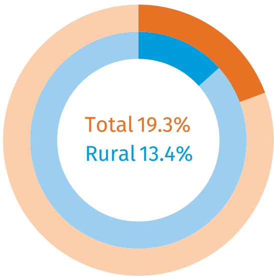
Figure 2. **Installed Electricity Capacity by Source in Niger in 2020 (MW)**



Source: IRENA[6]

The total electrification rate in Niger in 2020 was 19 per cent, with rural access being 13 per cent, one of the lowest in the region (Figure 3). By 2030, the country aims to reach 100 per cent electricity coverage in urban areas and 30 per cent in rural areas. According to the Project for the Electrification of Rural and Urban Areas (PEPERN), the plan should target at least 46,000 households.[9,10,11]

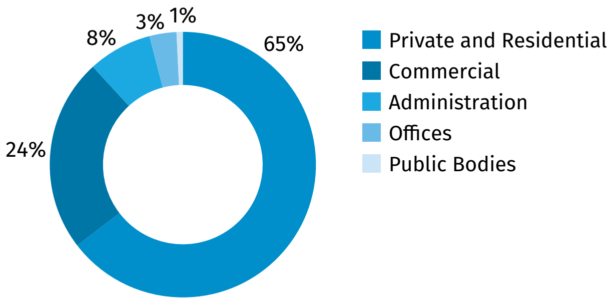
Figure 3. **Access to Electricity in Niger in 2020 (%)**



Source: World Bank[9]

In Niger, private and residential consumers represented the greatest share of electricity buyers (almost 65 per cent) and local public bodies the lowest (0.8 per cent) in 2020 (Table 1).[12]

Figure 4. **Consumption Rates by Consumer Category in Niger in 2020**



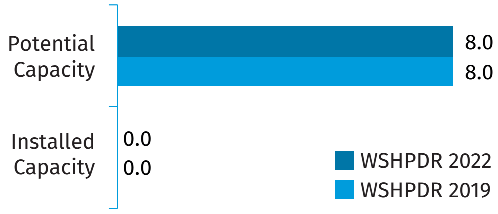
Source: NIGELEC[12]

The electricity subsector in Niger is regulated by the Regulation Authority of the Electricity Sector (ARSE), which is also responsible for advising the Ministry of Energy, Petroleum and Renewable Energies on electricity tariffs, among other duties.[13] Following Decree No. 2017-796/PRN/ME of 2017, electricity tariffs are fixed in Niger, between 0.097 USD/kWh and 0.22 USD/kWh depending on the consumer category (residential, commercial, etc.) and electricity requirement (low voltage, medium voltage, high voltage). There are also options for subscription-based billing for up to 21 USD per month.[14]

SMALL HYDROPOWER SECTOR OVERVIEW

Niger does not have an official definition for small hydropower (SHP). For the purposes of this chapter, the 10 MW definition will be followed. At the moment, Niger does not have any installed SHP capacity. A combined potential of 8 MW was identified on the four rivers that flow into the Niger River (Gorouol, Tapoa, Sirba and Mékrou). This potential remains untapped due to the seasonality of the Niger River's tributaries as well as the increase in droughts experienced by the country's water bodies. Both installed and potential capacity remain unchanged compared to the *World Small Hydropower Development Report (WSHPDR)* 2019 (Figure 5).[14,15]

Figure 5. **Small Hydropower Capacities in the WSHPDR 2019/2022 in Niger (MW)**



Source: Ministry of Energy, Petroleum and Renewable Energies,[14] *WSHPDR 2019*[15]

In 2019, construction began on the Niger River of a dam and a 130 MW hydropower plant. The project, called the Kandadji Dam Project, is expected to be completed in 2031 and is a first step towards the prospective development of hydropower in Niger.[16]

RENEWABLE ENERGY POLICY

Niger is a member of the Economic Community of West African States (ECOWAS) and as such adopted the National Renewable Energy Action Plan (NREAP) that all 15 member-states adopted in 2015. The NREAP addresses all sources of renewable energy, including wind power, solar power, thermal power, tidal power and hydropower, and highlights the importance of their development and the contribution that renewable energy would bring to the country.

The NREAP specifies the need for the development of hydropower through the construction of the 130 MW Kandadji plant, a 122 MW hydropower plant in Gambou and a 90 MW hydropower plant in Namarigoungou. These plants are expected to contribute greatly to the country's energy mix. Under the NREAP, Niger is committed to exploiting its renewable energy potential to achieve universal electricity coverage by 2030.[14]

The renewable energy potential in the country is mostly untapped. In 2018, with the support of the World Bank, Niger launched the Niger Solar Electricity Access Project (NESAP). The project of approximately USD 50 million (USD 4.4 million from a donation and a USD 45.55 million loan) aims at improving access to electricity through solar power. NESAP falls within the Renaissance Act 2 of the Republic of Niger aimed at improving the rural electrification rate. In order to reach its targets, Niger has received funds from the International Development Association (AID).[17]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

There is currently no legislation regulating SHP as there is no developed hydropower in Niger. The main legislation and regulations documents in Niger concerning the electricity subsector include:

- Law No. 2016-05 (2016) on the electricity code;
- Law No. 2015-58 (2015) on the creation of the ARSE;
- Order No. 2010-09 (2010) on the Water Code.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Extreme precipitation variability in the Sahel region has affected hydropower in the Sahelian countries. This variability has also resulted in increased droughts and seasonality of the Niger River's tributaries, which considerably affects SHP development prospects.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The development of SHP projects in Niger is mainly hampered by:

- Irregularity of rainfall patterns, which affects SHP development, further exacerbated by climate change;
- Lack of comprehensive renewable energy policy which would set specific goals, including for hydropower;
- Limited experience in hydropower as there is currently no hydropower plant in the country, although construction has begun on one and is expected to be completed in 2031;
- Dependence on fossil fuels for energy production.

Enablers for SHP development in Niger include:

- Its location within the ECOWAS region, which provides an opportunity for the country to learn from and acquire expertise in hydropower from other member countries with developed SHP;
- Identified SHP potential, which, if developed, would improve electrification rates in the country.

REFERENCES

1. World Bank (2020). *Population, Total – Niger*. Available at https://data.worldbank.org/indicator/SP.POP.TOTL?locations=NE (Accessed 26 May 2022).
2. World Bank (2020). *Land Area (Sq. Km)* – Niger. Available at https://data.worldbank.org/indicator/AG.LND.TOTL.K2?locations=NE (Accessed 26 May 2022).
3. United States Geological Survey (n.d.). *Ecoregions and Topography of Niger*. Available at https://eros.usgs.gov/westafrica/ecoregions-and-topography/ecoregions-and-topography-niger (Accessed 26 May 2022).
4. Climate Change Knowledge Portal (2020). *Climatology – Niger*. Available at https://climateknowledgeportal.worldbank.org/country/niger/climate-data-historical#:~:text=As%20part%20of%20the%20West,to%20the%20West%20African%20monsoon (Accessed 26 May 2022).
5. Niger Diaspora (2006). *Geographie du Niger*. Available at http://nigerdiaspora.net/index.php/component/k2/item/10439-g%C3%A9ographie-du-niger [in French] (Accessed 26 May 2022).
6. International Renewable Energy Agency (IRENA) (2021). *Energy Profile – Niger*. Available at https://www.irena.org/IRENADocuments/Statistical_Profiles/Africa/Niger_Africa_RE_SP.pdf (Accessed 26 May 2022).
7. Niger Electric Company (NIGELEC) (n.d.). *Présentation*. Available at https://nigelec.net/page-d-exemple/presentation/ [in French] (Accessed 27 May 2022).
8. Raach, J. (2014). *Stratified Energy Access in Niger*. Available at https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwj8t4PsgIfcAhWPCqYKHeajCyIQFggrMAA&url=https%3A%2F%2Fraachsolar.com%2Fwp-content%2Fuploads%2F2015%2F12%2F2014_04_24_stratified_energy_access_in_niger_study.pdf&usg=AOvVaw33Myjg7-EhThla9Lnmj4Uv (Accessed 27 May 2022).
9. World Bank (2020). *Access to Electricity (% of Population – Niger)*. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=NE (Accessed 27 May 2022).
10. World Bank (2020). Access to Electricity, Rural (% of Rural Population). Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS?locations=NE (Accessed 27 May 2022).
11. African Development Bank Group (AfDB)(2016). *Niger - Rural, Semi-Urban and Urban Electrification Project in Niger (PEPERN) - Summary ESMP - 11 2016*. Available at https://www.afdb.org/fr/documents/document/niger-rural-semi-urban-and-urban-electrification-project-in-niger-pepern-summary-esmp-11-2016-92600/ (Accessed 27 May 2022).
12. Niger Electric Company (NIGELEC) (2020). *Rapport d'Activités 2020*. Available at https://nigelec.net/wp-content/uploads/2021/10/Rapport-activites-nigelec-2020-VF.pdf [in French] (Accessed 27 May 2022).
13. Regulation Authority of the Electricity Sector (ARSE) (2017). *Roles de l'ARSE Definis dans la Loi N°2016-05 Du 17 Mai 2016 Portant Code de L'electricite*. Available at http://www.arse.ne/wp-content/uploads/2022/03/Missions-de-lARSE-definies-dans-le-code-de-lelectricite-2016.pdf [in French] (Accessed 27 May 2022).
14. Ministry of Energy (2017). *Decree No. 2017-796/PRN/ME*. Available at https://rise.esmap.org/data/files/library/niger/Documents/Energy%20Access/Niger_Decret%202017-796.pdf [in French] (Accessed 27 May 2022).
15. Ministry of Energy, Petroleum and Renewable Energies (2015). *Plan d'Actions National des Energies Renouvelables (PANER)*. Available at https://www.se4all-africa.org/fileadmin/uploads/se4all/Documents/Country_PANER/Niger_Plan_d_Actions_National_des_Energies_Renouvelables.pdf [in French] (Accessed 28 May 2022).
16. UNIDO, ICSHP (2019). *World Small Hydropower Develop-*

ment Report 2019. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.

17. World Bank (2020). *Kandadji Niger Basin Water Resources Program*. Available at https://www.worldbank.org/en/country/niger/brief/kandadji-project (Accessed 17 June 2022).
18. Actuniger (2018). *Energies Renouvelables: avec le NESAP, l'ANPER mise sur le solaire pour eclairer les villages.* Available at https://www.actuniger.com/societe/13864-energie-renouvelables-avec-le-nesap-l-anper-mise-sur-le-solaire-pour-eclairer-plus-de-villages.html [in French] (Accessed 28 May 2022).

Nigeria

Paola Estenssoro Solíz and Cleber Romao Grisi, WHITEnergy Bolivia

KEY FACTS

Population	206,139,587 (est. 2020)[1]
Area	923,768 km^2 [2]
Topography	Nigeria is dominated by plains in the north and the south, with an average elevation of 609.5 metres. In the north, the Jos Plateau rises abruptly to a height of 1,219 metres in the Hausa Plains, reaching 1,781.6 metres in the Shere Hills. The eastern border with Cameroon is marked by an almost continuous chain of mountains, the Eastern Highlands, which rise to approximately 2,419 metres at the Chappal Waddi, the highest point in Nigeria. The Atlantic coastline is in the south of the country.[3]
Climate	Nigeria has a tropical climate with rainy and dry seasons, which vary depending on the location. The climate is hot and wet most of the year in the south-east of the country, but dry in the south-west and further inland. In the south, the rainy season lasts from March to November with a short dry season during August, referred to as the August Break, whereas in the far north it lasts from mid-May to September. The temperatures also vary a lot: in the north, winters are warm and dry reaching up to 40 °C, while northern hilly areas occasionally experience temperatures close to freezing (0 °C). By February, temperatures increase across all inland areas, reaching 40 °C in the centre-north from March to May. From June to September, the air is humid and sky is usually cloudy throughout the country, with uniform temperatures of 28–30 °C.[4,5]
Climate Change	Climate change projections for Nigeria predict an increase in maximum temperatures of 1.8–2.2 °C by the middle of the 21st century and of 2.2–4.5 °C by the end of the century, relative to the 1970–2000 period. The increase in maximum temperatures is expected to be the highest in the northern inland parts of the country, moderate in the centre and lowest in the coastal areas. This would reverse the trend observed during the 1970–2000 period, when the increase in temperatures was more significant on the coast than inland.[6]
Rain Pattern	The mean annual rainfall in the country is between 2,540 mm and 4,064 mm. The driest area in the country is the extreme north-east, where the average annual precipitation is below 500 mm, while in the central region it exceeds 2,000 mm and in the south-east 3,000 mm. The north of the country is drier than the south due to the influence of the coast line.[3,5,7]
Hydrology	There are three major basins in Nigeria: the Niger-Benue basin, the Lake Chad basin and the Gulf of Guinea basin. The Niger and the Benue Rivers are the two most important rivers in Nigeria. The two rivers converge at Lokoja forming a Y-shaped confluence and flow into the Niger Delta, one of the world's largest arcuate fan-shaped river deltas, before discharging into the Atlantic Ocean. Rivers in Nigeria generally show a marked seasonal variation in stages and discharges. The distribution of average monthly water levels at some gauging stations shows that a large proportion of the annual runoff occurs in the rainy season, occasionally causing floods. During the dry season, some of the smaller streams, especially in the northern parts of the country, virtually dry up, while the larger rivers are reduced to only a small fraction of their rainy season discharge.[3,4]

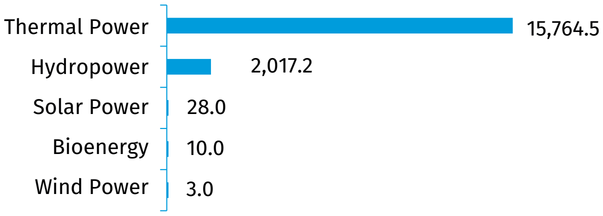
ELECTRICITY SECTOR OVERVIEW

As of 2020, Nigeria had a total installed capacity of 17,822.7 MW. Of this total, thermal power accounted for 15,764.5 MW (88 per cent), primarily provided by gas-fired power plants. Hydropower provided 2,017.2 MW (11 per cent) and the remaining 41 MW (less than 1 per cent) were provided by wind power, solar power and bioenergy (Figure 1).[8,9,10,11]

Most of the electricity capacity in Nigeria is connected to the national grid, with the exception of small hydropower (SHP) and wind power. Since the electricity supply from the national grid is insufficient and unstable, electricity production on isolated networks, mainly for self-consumption, plays a prominent role in the country.[12]

In 2021, there were 29 power plants suppling electric energy to the national grid, of which 4 were hydropower plants and 25 thermal plants. The main sources of hydropower are the Kainji (760 MW), Jebba (570 MW) and Shiroro (600 MW) hydropower plants.[8,9,13]

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

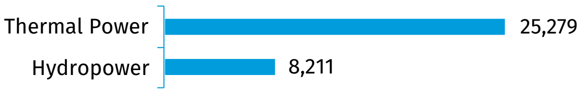


Source: NERC,[8,9] IRENA,[10] Romao Grisi & Estenssoro Solíz[11]

The transmission network of the national gird has a total length of 12,300 kilometres (5,650 kilometres of 330 kV lines and 6.687 kilometres of 132 kV lines) and connects 32 330 kV and 105 132 kV substations. The distribution network has a length of 224,838 kilometres consisting of 33 kV, 11 kV and low-voltage lines.[14]

In 2019, the generation of electricity in Nigeria was approximately 33,489 GWh. Thermal power provided nearly 25,279 GWh (75 per cent) of this total and hydropower provided nearly 8,211 GWh (25 per cent), while generation from other energy sources was negligible (Figure 2).[9]

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

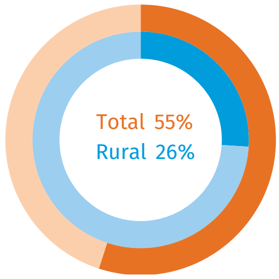


Source: NERC[9]

Although Nigeria is the largest economy in Africa, the national electrification rate stood at 60 per cent in 2018, leaving approximately 16 million households without access to electricity.[15] In 2019, nationwide electricity access declined to slightly over 55 per cent, urban electricity access stood at 84 per cent, while rural electricity access was approximately 26 per cent (Figure 3).[16] The majority of the rural population in Nigeria do not have access to electricity and shortages of electric energy production in rural areas hinder the development of the country.[12,17] In addition, the electricity supply in most parts of the country is unreliable due to frequent power outages caused by failures occurring on the main transmission grid as well as on the distribution networks, forcing consumers (both industrial and residential) to rely on diesel or petrol generators to meet their electricity needs.

The national electricity regulator is the Nigerian Electricity Regulatory Commission (NERC), an independent regulatory body established in 2005 as part of a process that effectively ushered in the privatization of electric power services in the country. The primary function of the NERC is to regulate electricity tariffs issued by both private and public generating companies. Additional responsibilities of the NERC include licensing operators, determining codes and standards, establishing customer rights and obligations and setting cost-reflective industry tariffs. Since its inception, the NERC has worked to facilitate the expansion of generating capacity and the national grid through the issuance of licences for the generation, transmission and distribution of electricity, as well as the development of codes and industry standards, market rules and a multi-year tariff structure.[18]

Figure 3. **Electricity Access Rate in Nigeria in 2019 (%)**



Source: World Bank[16]

In March 2020, the NERC initialized a transition from demand-based to cost-reflective and service-reflective electricity tariffs. Following these changes, consumer tariff rates are now based on the duration of the daily electricity service, with different service duration minimums applied to each of the five consumer classes:

- Residential (R): A consumer who uses the premises exclusively as a residence — house, flat or multi-storied house; minimum daily duration of service of 20 hours;
- Commercial (C): A consumer who uses the premises for any purpose other than exclusively as a residence or as a factory for manufacturing goods; minimum of 16 hours;
- Industrial (D): A consumer who uses the premises for manufacturing goods, including welding and ironmongery; minimum of 12 hours;
- Special (A): Consumers such as agriculture and agro-allied industries, water boards, religious houses, government and teaching hospitals, government research institutes and educational establishments; minimum of 8 hours;
- Street Lights (S): minimum of 4 hours.[18,19]

Additionally, electricity tariffs in Nigeria vary by region as well as by connection type for each consumer class. Table 1 displays residential tariffs across different regions of Nigeria in 2022. It must be noted than although the tariffs have been on a decreasing trend in recent years, they are still relatively high, as the duration of supply is limited and only a fraction of the population is connected to the grid in many areas.

Table 1. **Electricity Distribution Tariffs for Residential Users in Nigeria in 2022**

Region	Price by connection type (NGN/kWh (USD/kWh))				
	Lifeline	Single-phase	Three-phase	Low-voltage maximum demand	High-voltage maximum demand
Abuja	4.00 (0.010)	19.51 (0.047)		37.12 (0.089)	
Benin	4.00 (0.010)	24.49 (0.059)	26.94 (0.065)	31.69 (0.076)	
Enugu	4.00 (0.010)	20.76 (0.050)	23.01 (0.055)	32.30 (0.078)	30.93 (0.059)
Ibadan	4.00 (0.010)	20.98 (0.050)		37.53 (0.090)	
Jos	4.00 (0.010)	34.76 (0.083)		53.29 (0.128)	
Kaduna	4.00 (0.010)	19.50 (0.047)	23.01 (0.055)	30.42 (0.073)	34.71 (0.083)
Kano	4.00 (0.010)	18.60 (0.045)	24.47 (0.059)	35.24 (0.085)	
Ikeja	4.00 (0.010)	18.34 (0.044)	20.47 (0.049)	30.61 (0.073)	30.98 (0.074)
Port Harcourt	4.00 (0.010)	26.02 (0.062)		32.32 (0.078)	33.69 (0.081)
Eko	4.00 (0.010)	19.98 (0.048)	25.39 (0.061)	26.09 (0.063)	
Yola	4.00 (0.010)	22.25 (0.053)	24.36 (0.058)	44.5 (0.107)	0.00 (0.000)

Source: NERC[20]

SMALL HYDROPOWER SECTOR OVERVIEW

Hydropower in Nigeria is classified into six categories based on the range of installed capacity (Table 2). According to the national definition, small hydropower (SHP) includes plants between 1 MW and 30 MW of installed capacity.[21] In the current chapter, the national SHP definition of up to 30 MW is used for the purpose of comparing data with the *World Small Hydropower Development Report (WSHPDR) 2019*.

Table 2. **Classification of Hydropower in Nigeria**

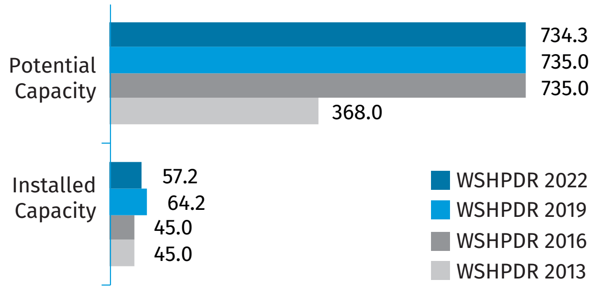
Category	Installed capacity (MW)
Pico	P < 0.1
Micro	0.1 ≤ P < 0.5
Mini	0.5 ≤ P < 1
Small	1 ≤ P < 30
Medium	30 ≤ P < 100
Large	P > 100

Source: Fagbohun,[12] Imo et al.[21]

SHP projects are generally considered in Nigeria to be more environmentally friendly than both large hydropower plants and power plants running on fossil fuels, because SHP projects generally do not involve significant deforestation or inundation of the surrounding area. The net cost savings resulting from the use of local materials and labour, standardized power plants and the relative ease of local development of the SHP technology make it attractive for remote and off-grid applications, while directly benefiting rural communities.[22,23] The diverse topography and abundant watercourses of Nigeria are likewise suitable for SHP.

There were 14 SHP plants up to 30 MW operating in Nigeria as of 2021, with a total installed capacity of 57.2 MW (Table 3).[12,21,22,24,25,26] All existing SHP plants are not connected to the national grid and mostly provide power to remote rural areas. The theoretical potential capacity for SHP up to 30 MW has been estimated at 3,500 MW, indicating that less than 2 per cent of the potential has been developed so far, while the economically-feasible undeveloped potential has been estimated at 734.3 MW.[12,27,28] Relative to the *World Small Hydropower Development Report (WSHPDR) 2019*, installed capacity decreased by nearly 11 per cent while potential capacity decreased slightly by less than 1 per cent, due to more accurate information becoming available (Figure 4).[29]

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



Source: Fagbohun,[12] Imo et al.,[21] Muhammadu & Usman,[22] Zarma,[24] Igweonu & Joshua,[25] Onyemaechi & Charles,[26] Nkwoh,[28] *WSHPDR 2019*,[29] *WSHPDR 2013*,[30] *WSHPDR 2016*[31]

Table 3. **List of Existing Small Hydropower Plants in Nigeria**

Name	Location	Capacity (MW)
Zungeru	Niger	10.000
Oyan	Ogun	9.000
Kurra	Plateau	8.000
Gyrara Dam	Niger	6.000
Kano	Tiga	6.000
Lere I	Plateau	4.000
Lere II	Plateau	4.000
Bakalor	Sokoto	3.000
Bagel II	Plateau	2.000
Ouree	Plateau	2.000
Kwali falls	Plateau	2.000

Name	Location	Capacity (MW)
Bagel I	Plateau	1.000
Waya Dam	Bauchi	0.150
Ezioma Mgobowo	Enugu	0.030
Evoboro	Edo	0.003
	Total	**57.183**

Source: Fagbohun,[12] Imo et al,[21] Muhammadu & Usman,[22] Zarma,[24] Igweonu & Joshua,[25] Onyemaechi & Charles[26]

Over the last decade, several new SHP projects have been launched in the country (Table 4). However, their current status and stage of completion are unclear. Additionally, studies have identified 278 potential SHP sites up to 30 MW with a total potential capacity of 734.3 MW.[12] Several potential undeveloped SHP sites available for investment are listed in Table 5. According to some estimates, a total demand of 3,315 MW could be fulfilled by SHP in Nigeria by 2030, provided sufficient investment is made.[22]

Table 4. **List of Selected Ongoing Small Hydropower Projects in Nigeria**

Name	Location	Capacity (MW)	Development stage
Challawa Gorge Dam	Kano	7.00	Dam construction completed; electromechanical system yet to be installed
Ikere Gorge Iseyin	Oyo	6.00	Dam construction completed; electromechanical system yet to be installed
Annoke Ugbokpo	Benue	1.20	Dam construction completed; electromechanical system yet to be installed
Tunga Dam	Taraba	0.40	Under construction
Gurara Dam	Niger	0.03	Under Construction

Source: Onyemaechi & Charles[26]

Note: As of 2013.

Table 5. **List of Selected Potential Small Hydropower Sites in Nigeria**

Name	Location	Potential Capacity (MW)
Jada Dam	Upper Benue River	5.000
Kiri Dam	Upper Benue River	1.083
Monkin Dam	Upper Benue River	0.500
Waya Dam	Upper Benue River	0.062
Dandinkowa Dam	Upper Benue River	0.033

Source: Zarma[24]

RENEWABLE ENERGY POLICY

Nigeria is actively in the process of developing renewable energy policies and strategic documents. In 2006, the Energy Commission of Nigeria (ECN) and the United Nations Development Programme (UNDP) created the Renewable Energy Master Plan (REMP), with a subsequent review in 2012.[32] The former Ministry of Power and Steel, in collaboration with the International Centre for Energy, Environment and Development (ICEED) put together the Renewable Electricity Policy Guidelines in 2006, focusing on the use of small-scale renewable energy sources for rural electrification, and launched the Renewable Electricity Action Programme (REAP) operationalizing the guidelines the same year. The Japan International Cooperation Agency (JICA), in collaboration with the Federal Ministry of Water Resources (FMWR), put together several Hydropower Master Plans in 1993, 1995 and 2013 and in 2007 the Solar Energy Master Plan. In 2007, the Nigerian National Petroleum Corporation (NNPC) issued the National Biofuel Policy and Incentives, which established a biofuel support programme aiming at integrating the agricultural sector with the downstream petroleum sector. Finally, the National Renewable Energy and Energy Efficiency Policy (NREEEP), adopted in 2015, provides an overarching framework for the development of renewable energy sources and energy efficiency, thereby functioning as an umbrella policy for the various existing documents.[12,23,25]

With regard to hydropower development, the aforementioned legislation, programmes and frameworks aim to fulfil the following goals:

- Fully harnessing the hydropower potential available in the country for electricity generation;
- Giving particular attention to the development of mini- and micro-hydropower projects;
- The exploitation of hydropower resources shall be done in an environmentally sustainable manner;
- The active promotion of private sector and indigenous participation in hydropower development.[25]

An important overarching development that had positive impacts on the expansion of renewable energy sources in Nigeria was the 2005 Electricity Sector Reform Law. The Law allowed private operators to apply for and obtain a licence through the NERC to build and operate a power plant with an aggregate capacity greater than 1 MW. The Law additionally established the Rural Electrification Agency (REA) together with an independent Rural Electrification Fund (REF), which holds as its primary objective the full integration of renewable energy sources into the energy options available for rural electrification.[23]

In February 2018, Nigeria completed the Renewable Energy and Energy Efficiency Partnership project, which supplied 261,938 citizens with clean renewable energy. This project was implemented in partnership with the US Agency for International Development (USAID), private donors, government agencies, financial institutions and non-governmental organizations. The goal of the project was to build connections to 2.5 MW of power through off- and on-grid sources, which is expected to reduce CO_2 emissions by 4.5 million metric tons.[33]

SMALL HYDROPOWER LEGISLATION AND REGULATION

The Federal Ministry of Environment (FME) is responsible for environmental impact assessment (EIA), to be implemented in accordance with the Environmental Impact Assessment Act (Decree No. 86) of 1992 and the guidelines promulgated in 1995. All development projects are classified in one of the following three categories based on the guidelines:

- Projects requiring a full EIA;
- Projects requiring a partial EIA primarily focused on environmental impact mitigation measures and an environmental plan (although a full-scale EIA is required if a project site is adjacent to an area with special environmental and social considerations);
- Projects with "essentially favourable impacts" on the environment, for which the FME prepares a simple environmental impact statement.

Additionally, the Policy for Managing Effluents and Discharges replaces the EIA with a simplified procedure for off-grid hydropower and captive generation below 10 MW.[14]

COST OF SMALL HYDROPOWER DEVELOPMENT

The purchase price of electricity from SHP plants in Nigeria necessary to ensure project payback within a reasonable timeframe ranges between 0.03 USD/kWh and 0.06 USD/kWh, making SHP an attractive source of electricity generation. The comparative costs of different renewable energy sources in Nigeria are provided in Table 6.[25]

Table 6. **Comparative Cost of RES development in Nigeria**

Technology	*Initial capital cost (USD/kW)*
Micro-hydropower, 10-20 kW	1,000–2,400
Solar power (PV), 0.070 kW	11,200
Solar power (PV), 0.090 kW	8,400
Wind power, 0.025 kW	5,500
Wind power, 4 kW	3,900
Wind power, 10 kW	2,800

Source: Igweonu & Joshua,[25]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The main barriers faced by the SHP sector in Nigeria include:

- Inadequate policy, institutional and regulatory frameworks to stimulate demand and attract investors. Although several policies and regulatory frameworks are in place to promote renewable energy-based electricity generation, there is no definite and well-framed pathway to making these policies successful.
- High initial investment costs of SHP development relative to those for large hydropower.
- Inadequate private sector participation in SHP development. So far, the private sector is only actively involved in the importation and marketing of renewable energy components. Full participation by the private sector in all aspects of SHP development, especially in the form of investment towards local fabrication of turbines, will enhance the development of SHP.
- Limited access to relevant data. The recent unbundling of the Power Holding Company of Nigeria into different companies under the privatization programme has made the process of acquiring relevant data for SHP development challenging.
- Lack of public awareness of the potential and benefits of SHP as a viable source for electricity generation.
- Insufficient skilled labour for developing SHP projects.

The primary enablers for SHP development in the country could be defined as:

- The very significant untapped potential SHP capacity;
- The urgent need to extend electrification to many parts of the country undersupplied with electricity and beyond the reach of the current transmission and distribution networks.

REFERENCES

1. United Nations Department of Economic and Social Affairs (2019). *World Population Prospects 2019*. Available at https://population.un.org/wpp/Download/Standard/Population/ (Accessed 16 January 2022).
2. Nations Encyclopedia (n.d.). *Nigeria – Location, size, and extent*. Available at https://www.nationsencyclopedia.com/Africa/Nigeria-LOCATION-SIZE-AND-EXTENT.html (Accessed 16 January 2022).
3. Nigeria Federal Surveys (1978). *The National Atlas of the Federal Republic of Nigeria*.
4. Encyclopaedia Britannica (n.d.). *Climate of Nigeria*. Available at https://www.britannica.com/place/Nigeria/Climate (Accessed 16 January 2022).
5. Climates to Travel (n.d.). *Climate – Nigeria*. Available at https://www.climatestotravel.com/climate/nigeria (Accessed 16 January 2022).
6. Federal Ministry of the Environment (2014). *Nigeria's Second National Communication under the United Nations Framework Convention on Climate Change*. Available at https://unfccc.int/sites/default/files/resource/nganc2.pdf (Accessed 16 January 2022).
7. Adamu, J.I. (2020). *Overview of the 2020 Seasonal Rainfall Prediction*. Nigerian Meteorological Agency. Available at https://fscluster.org/sites/default/files/documents/2020_srp_fss_abuja.pdf (Accessed 16 January 2022).
8. Nigerian Electricity Regulatory Commission (NERC) (2021). *NERC Daily Reports (2021).* [not publicly available]
9. Nigerian Electricity Regulatory Commission (NERC) (2020). *NERC Quarterly Reports (2019).* Available at https://nerc.gov.ng/index.php/library/documents/NERC-Reports/

NERC-Quarterly-Reports/ (Accessed 17 January 2022).
10. International Renewable Energy Agency (IRENA) (2021). *Energy profile – Nigeria*. Available at https://www.irena.org/IRENADocuments/Statistical_Profiles/Africa/Nigeria_Africa_RE_SP.pdf (Accessed 17 January 2022).
11. Romao Grisi, C. & Estenssoro Solíz, P. (2021). Authors' personal expertise, background research and communication with stakeholders.
12. Fagbohun, O. O. (2016). Studies on small hydro-power potentials of Itapaji Dam in Ekiti State, Nigeria. *International Journal of Engineering Science Invention*, *5*(1), 28-36.
13. Falobi, E. O. (1985). The Role of Renewables in Nigeria's Energy Policy Mix. *Gas*, *1*, 941.
14. Energypedia (n.d.). *Nigeria Energy Situation*. Available at https://energypedia.info/wiki/Nigeria_Energy_Situation (Accessed 17 January 2022).
15. GET.invest (n.d.). *Nigeria – Energy Sector Investment Overview*. Available at: https://www.get-invest.eu/market-information/nigeria/energy-sector/ (Accessed 18 January 2022).
16. World Bank (n.d.). *Access to electricity (% of population) – Nigeria*. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=NG (Accessed 18 January 2022).
17. United States Energy Information Administration (EIA) (2019). *Nigeria*. Available at https://www.eia.gov/international/overview/country/NGA (Accessed 18 January 2022).
18. Nigerian Electricity Regulatory Commission (NERC) (n.d.). *Official website*. Available at https://nerc.gov.ng/index.php (Accessed 18 January 2022).
19. Nigerian Electricity Regulatory Commission (NERC) (n.d.). *How much do I pay for electricity?* https://nerc.gov.ng/index.php/home/consumers/how-much-do-i-pay-for-electricity (Accessed 18 January 2022).
20. Nigerian Electricity Regulatory Commission (NERC) (2015). *MYTO-2015 Distribution Tariffs (2015-2024).* Available at https://nerc.gov.ng/index.php/library/documents/MYTO-2015/NERC-MYTO-2015-Distribution-Tariffs-(2015---2024)/ (Accessed 18 January 2022).
21. Imo, E. E., Olayanju, A., Ibikunle, F. A. & Dahunsi, S. O. (2020). Impact of small hydropower developments on rural transformation in Nigeria. In (Vol *IOP Conference Series: Earth and Environmental Science, 445*(1) p. 012023.
22. Muhammadu, M. M. & Usman, J. (2014). Small Hydropower Development in North-Central of Nigeria: An Assessment. *Journal of Advanced Review on Scientific Research*, *2*(1), 41-50. Available at https://www.academia.edu/download/36528621/5Full_Text.pdf (Accessed 18 January 2022).
23. Ohunakin, O. S., Ojolo, S. J. & Ajayi, O. O. (2011). Small hydropower (SHP) development in Nigeria: An assessment. *Renewable and Sustainable Energy Reviews*, *15*(4), 2006-2013. Available at https://core.ac.uk/download/pdf/79124831.pdf (Accessed 18 January 2022).
24. Zarma, I.H. (2006). *Hydro Power Resources in Nigeria*. Country position paper presented at 2nd Hydro Power for Today Conference, International Centre on Small Hydro Power (IC-SHP), Hangzhou, China 2006. Available at https://www.researchgate.net/publication/321184693_HYDRO_POWER_RESOURCES_IN_NIGERIA (Accessed 18 January 2022).
25. Igweonu, E. I. & Joshua, R. B. (2012). Small hydropower (SHP) development in Nigeria: Issues, challenges and prospects. *Global Journal of Pure and Applied Sciences*, *18*(1), 53-58. Available at https://www.ajol.info/index.php/gjpas/article/download/78921/69241 (Accessed 18 January 2022).
26. Onyemaechi, A. B. & Charles, I. (2013). Small Hydropower Projects for Rural Electrification in Nigeria: A Developer's Perspective. *International Journal of Innovative Technology and Exploring Engineering (IJITEE), 3*(5), 29-35.
27. Energy Commission of Nigeria (ECN) (2013). *National Energy Masterplan*. Available at https://rise.esmap.org/data/files/library/nigeria/Clean%20Cooking/Supporting%20Documentation/Nigeria_National%20Energy%20Master%20Plan%20Draft.pdf (Accessed 31 May 2022).
28. Nkwoh, B.N. (2021). *Nigeria – Country Commercial Guide. Electricity and Power Systems*. Available at https://www.trade.gov/country-commercial-guides/nigeria-electricity-and-power-systems (Accessed 18 January 2022).
29. 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.
30. 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.
31. 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.
32. Energy Commission of Nigeria (ECN) (2005). *Renewable Energy Master Plan*. Available at https://www.iceednigeria.org/resources/nov.-2005.pdf (Accessed 31 May 2022).
33. Bungane, B. (2018). *USAID completes renewable energy project in Nigeria*. ESI Africa. Available at https://www.esi-africa.com/industry-sectors/energy-efficiency/usaid-completes-renewable-energy-project-nigeria/ (Accessed 18 January 2022).

Senegal

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

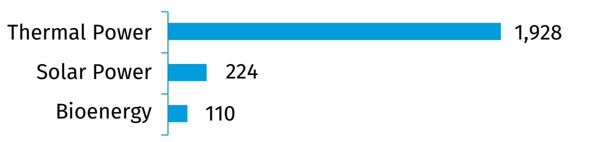
KEY FACTS

Population	16,743,930 (2020)[1]
Area	196,722 km^2 [2]
Topography	Senegal is a relatively flat country within the depression known as the Senegal-Mauritanian Basin. The north of the country presents dunes from Cap Vert to Saint-Louis. The south has muddy estuaries and includes the greener Casamance Region, which presents a more varied relief and is separated from the rest of the country by the Republic of the Gambia. The south-east is home to the Tamgué foothills, which rise up to a maximum altitude of 581 metres. The north-west is mostly a semi-desert, but the centre and much of the south, except for the forests of the Casamance, are open savannah country.[3]
Climate	Senegal has a tropical dry climate with three climate zones (coastal, Sahelian and Sudanic) and two distinct seasons: a dry season from October to May and a rainy season from June to September. The mean annual temperature is 28.6 °C, while the monthly averages in the hottest seasons can reach 35 °C. The colder months can bring temperatures as low as 14 °C, particularly in January.[4,5]
Climate Change	Between 1961 and 2010, Senegal has seen an overall increase in temperatures ranging from 0.58 °C to 1.88 °C. Decreases in precipitation were also recorded as well as irregular and unpredictable rainfall patterns throughout the country. There has been an increase in both droughts and floods in recent years and a recorded rise in sea level.[4]
Rain Pattern	The coastal climate zone, which occurs along the Atlantic coastline, experiences rainfall from June to October with an average annual rainfall of approximately 500 mm. The Sahelian climate zone, an area between the Senegal River to the north and a line running from the town of Thiès to the neighbouring Mali, experiences average precipitations of 360 mm. The Sudanic climate zone occurs in the southern half of the country and brings precipitation averages between 740 mm and 1,270 mm. The mean annual precipitation in Senegal is 713.8 mm.[4,5]
Hydrology	The main rivers in Senegal are the Senegal, Gambia and Casamance Rivers. The Senegal River, considered the most important waterway as it passes a long route through the interior of the country, flows through the mountain masses of the east, rising at the Fouta Djallon foothills and rapidly falls before reaching the Senegalese territory. The river then forms the False Delta at Dagana, supplying Lake Guier.[2]

ELECTRICITY SECTOR OVERVIEW

The main sources of electricity in Senegal are thermal power and solar power, accounting for 85 per cent and 10 per cent, respectively, of the total electricity production of 2,263 GWh in 2019. Production from renewable bioenergy accounted for 110 GWh, or 5 per cent of the total production, in 2019 (Figure 1).[6]

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



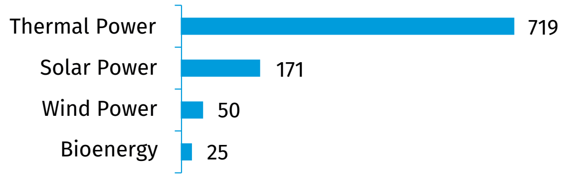
Source: IRENA[6]

The electricity sector in Senegal is overseen by the Ministry of Petroleum and Energy and regulated by the Regulatory Commission for Electricity Sector (CRSE). The CRSE works with Senelec, the national utility, and the Agency for Rural Electrification (ASER) to regulate production, supply and distribution within the country and in the regional West African Power Pool (WAPP).[7]

In Senegal, independent power producers (IPP) have a relatively strong presence and contribute greatly to electricity generation. This is a result of Law No. 98-29 of 1998 that created the ASER, which oversees public-private partnerships for the development of the electricity sector and attracts IPPs. These IPPs include the Moroccan ONE, EDF-Matforce, ENCO/ISOFOTON Maroc, the group STEG-Coselec-LCS, Kolda Energy and Electricité du RIP (EDR), all operating in rural Senegal.[8,9]

In 2020, power plants in Senegal had a combined installed capacity totalling 965 MW, of which thermal power, solar power, wind power and renewable bioenergy contributed 719 MW (or 74 per cent), 171 MW (or 18 per cent), 50 MW (or 5 per cent) and 25 MW (or 3 per cent), respectively (Figure 2).

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

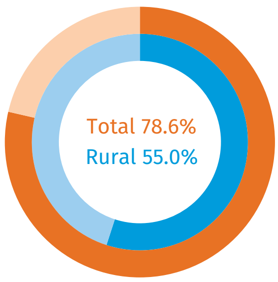


Source: IRENA[6]

Senegal is a member country of the Economic Community of West African States (ECOWAS). The ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) aims to support the development of renewable energy sources and energy action plans in the member states. Senegal is also part of the West African Power Pool (WAPP), a regional organization dedicated to fostering greater cooperation in the region's power sector and interconnection among countries to enhance energy security.[10]

Senegal has one of the highest electrification rates in Africa at almost 79 per cent in 2020, with a 55 per cent rural access rate (Figure 3).[11]

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



Source: World Bank[11]

Electricity tariffs in Senegal vary depending on the provider, though not considerably. The largest provider is, by far, Senelec, which in 2020 charged tariffs ranging from 0.15 USD/kWh to 0.29 USD/kWh depending on the level of consumption. The tariffs are set by the CRSE.[9]

SMALL HYDROPOWER SECTOR OVERVIEW

Small hydropower (SHP) in Senegal refers to hydropower plants with a capacity of up to 10 MW. There are currently no SHP plants on the territory of Senegal and no potential sites have been officially identified due the flat topography of the country that is unfavourable for the development of SHP.

RENEWABLE ENERGY POLICY

Senegal was one of the first countries in West Africa to pass a renewable energy (RE) law, the Renewable Energy Policy Law of 2010, and is one of the most committed to strengthening institutional framework in the RE sector.[12]

The Government of Senegal launched the Energy Sector Development Policy Letter of 31 October 2012, pursuant to Act No. 2010-21 on the Renewable Energy Policy Law of 20 December 2010 and Decree No. 2011-2013 on the Implementation of the Renewable Energy Act. The decree set the conditions for the purchase and remuneration of electricity from RE sources. The Renewable Energy Law provides a legal framework for tax exemptions for the purchase of equipment necessary to develop RE production for domestic use. The law also created the foundation for a feed-in tariff (FIT) scheme.[8,13]

In order to promote and develop the RE sector through a favourable legislative and regulatory framework, the National Renewable Energy Agency (ANER) was created by Order 2013-684 and a Centre for Studies and Research into Renewable Energy was launched at the University Cheikh Anta Diop of Dakar for the purpose of conducting studies on RE potential in Senegal.[13]

The national economic and social development plan of Senegal, the Plan for an Emerging Senegal (PSE 2025), highlights the importance of RE development in the country through the goal of at least a 23 per cent share of on-grid RE in power generation by 2030. As part of the PSE 2025, a National Action Plan for Renewable Energies (PANER) was designed with specific targets for 2025, including:

- Power of 440 MW from different sources (solar photovoltaics (PV) and wind power);
- RE penetration rate of 30 per cent.[13]

In the capital city of Dakar, the Environmental Action Plan (PACTE) and the Master Plan for Urban Development of Dakar and Its Surroundings (PDU 2035) aim for a 15 per cent share of RE and a reduction of diesel share in local generation mix from 90 per cent in 2013 to 5 per cent by 2035. The City of Dakar has also finalized the Territorial Energy Climate Plan (PCET), an integrated energy and climate change development plan informing the city's short- and long-term RE roadmap as part of its commitment to the C40 Cities Leadership Programme. Through the PCET, the Government of Senegal also plans to equip over half of all municipal buildings in the capital with rooftop grid-connected solar PV by 2030.[14]

BARRIERS AND ENABLERS TO SMALL HYDROPOWER DEVELOPMENT

The development of SHP projects in Senegal is hampered mainly by:

- Flat terrain;
- Deficient infrastructure, as there is inadequate maintenance of larger hydropower plants;

- Lack of local capacity for the installation and maintenance of SHP plants;
- Limited comprehensive mapping of RE sources in key areas;
- Limited availability of hydrological data.

Enablers for SHP development in Senegal include:
- Government support for the development of RE in general;
- Strong institutional framework for RE, including large hydropower, which could be reformed to include SHP.

REFERENCES

1. World Bank (2020). *Population, Total – Senegal*. Available at https://data.worldbank.org/indicator/SP.POP.TOTL?locations=SN (Accessed 2 May 2022).
2. Encyclopaedia Britannica (2018). *Senegal*. Available at https://www.britannica.com/place/Senegal (Accessed 2 May 2022).
3. Nations Encyclopedia (n.d.). *Senegal – Topography*. Available at https://www.nationsencyclopedia.com/Africa/Senegal-TOPOGRAPHY.html (Accessed 2 May 2022).
4. Climate Change Knowledge Portal (2020). *Senegal – Climatology*. The World Bank. Available at https://climateknowledgeportal.worldbank.org/country/senegal/climate-data-historical (Accessed 2 May 2022).
5. Britannica (2021). *Climate of Senegal*. Available at https://www.britannica.com/place/Senegal/Climate (Accessed 2 May 2022).
6. International Renewable Energy Agency (IRENA) (2021). *Energy Profile – Senegal*. Available at https://www.irena.org/IRENADocuments/Statistical_Profiles/Africa/Senegal_Africa_RE_SP.pdf (Accessed 2 May 2022).
7. Electricity Regulatory Board (CRSE) (n.d.). *Les institutions*. Available at https://www.crse.sn/les-institutions [in French] (Accessed 2 May 2022).
8. Itoua, I. & Atteib, M. (2021). *Africa Energy Futures: Senegal*. Available at https://www.dlapiper.com/en/africa/insights/publications/2021/11/africa-energy-futures/africa-energy-futures-senegal/ (Accessed 2 May 2022).
9. Electricity Regulatory Board (CRSE) (2019). *Rapport Annuel 2019*. Available at https://www.crse.sn/sites/default/files/2021-04/Rapport%20Annuel%202019%20CRSE.pdf [in French] (Accessed 2 May 2022).
10. Abdulrahman, J. & Paco, D. (2020). *Regional Progress Report on Renewable Energy, Energy Efficiency and Energy Access in ECOWAS region Monitoring year: 2018*. ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE). Available at http://www.ecreee.org/sites/default/files/documents/regional_progress_report_2018_final.pdf (Accessed 2 May 2022).
11. World Bank (2022). *Project Appraisal Document on a Proposed Credit in The Amount of Eur 132.6 Million (USD150.0 Million Equivalent) From the Scale-Up Window to The Republic of Senegal for an Energy Access Scale Up Project (Padaes).* Available at https://documents1.worldbank.org/curated/en/142041645128048730/pdf/Senegal-Energy-Access-Scale-Up-Project-PADAES-Project.pdf (Accessed 2 May 2022).
12. International Renewable Energy Agency (IRENA) (2013). *Renewables Readiness Assessment: Senegal*. Available at https://www.irena.org/publications/2013/Jan/Senegal-Renewables-Readiness-Assessment-2012#:~:text=Senegal%20is%20very%20committed%20to,yearly%20capacity%20of%2025%20MW. (Accessed 5 May 2022).
13. Ba, A. (2018). *The Energy Policy of the Republic of Senegal: Evaluations and Perspectives*. Available at https://hal.archives-ouvertes.fr/hal-01956187/document (Accessed 5 May 2022).
14. REN21 (2021). *Dakar – Senegal*. Available at https://www.ren21.net/cities-2021/cities/dakar/dakar/ (Accessed 5 May 2022).

Sierra Leone

International Center on Small Hydro Power (ICSHP)

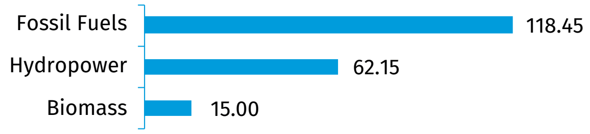
KEY FACTS

Population	8,238,175 (2022)[1]
Area	71,740 km^2 [2]
Topography	The western part of the country, the Sierra Leone Peninsula, is a mountainous area that slopes down to the coastal plain in the east and extends inland for 100–160 kilometres. The north-east is characterized by stretches of wooded hills that lead to a plateau region lying at an elevation of 300–610 metres. The highest point is Loma Mansa (Bintimani) at 1,948 metres. The relief is drained by a system of rivers flowing through cataracts and waterfalls. They are navigable for short distances and are ideal for hydropower development and providing water for the rural communities.[3,4]
Climate	Sierra Leone has a tropical climate, with inland areas having a temperate climate and coastal areas having a hot and humid weather. The annual temperatures average 26.5 °C. The dry season lasts from November to April, brings harmattan winds from the Sahara Desert and results in sandstorms and little precipitation. The wet season, lasting from May to October, is characterized by winds from the south-western monsoon.[3,5]
Climate Change	Sierra Leone has been experiencing increasing dry spells, which, combined with low-moisture content in the soil, affect farming production. Dry spells are often interrupted by torrential rains making the rainfall pattern irregular and harder to adapt to. The rise in sea level has also translated into frequent and severe floods, which, combined with deforestation, saturate the soil leading to catastrophic mudslides and landslides. The annual precipitation pattern has become erratic in the last 50 years, with delayed starts to the rainy season. The pre-monsoon period from April to June has come to be associated with more frequent rains and storms as well as stronger winds. The September to November period, which was characterized by rather frequent thunderstorms usually, has become calmer and drier. The harmattan has also been observed to be warmer in recent years and the average annual temperatures have increased by 0.8 °C since 1960.[4,5,6]
Rain Pattern	The coast and the mountains receive more than 5,800 mm of rainfall annually, while the rest of the country receives approximately 3,150 mm. There are three climatic belts: from the coast to 80 kilometres inland, with rainfall greater than 3,300 mm per annum; 80–190 kilometres inland, with an average annual rainfall of 2,500–3,300 mm; and from 190 kilometres inland to the border areas, with an average annual rainfall of 1,900–2,500 mm.[3,4,5]
Hydrology	The country has 12 river basins. Five are shared with Guinea and two with Liberia. The most important rivers are the Kolente (Great Scarcies), Kaba, Rokel, Pampana (Jong), Sewa, Moa and Mano. Seasonal variation affects the flow, which is lowest in April, as only 11–17 per cent of discharge occurs from December to April.[3]

ELECTRICITY SECTOR OVERVIEW

The energy sector in Sierra Leone is heavily dependent on imported petroleum, hydropower and biomass. Of the 195.6 MW of installed capacity in 2020, renewable energy accounted for 39 per cent and petroleum accounted for 61 per cent (Figure 1). The total electricity generated in the same year was 696 GWh, of which renewable energy represented 45 per cent and fossil fuel 55 per cent.[7]

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

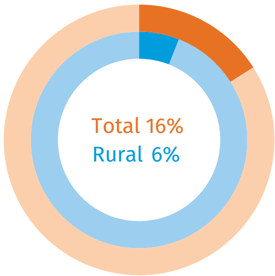


Source: AF-Mercados (IRP)[7]

There are recent projects to increase electricity supply to Sierra Leone. These include the completed Cote D'Ivoire-Liberia-Sierra Leone-Guinea (CLSLG) transmission line, which, for Sierra Leone, consists of a 225 kV power line that covers the districts of Kenema, Pujehun, Kono, Koinadugu, Tonkolili, Kambia, Bombali and Karene. There is also an Exim Bank–funded project for the construction of a 225 kV power line passing through the towns of Yiben, Fadugu, Port Loko, Waterloo, Kent, Sussex and Goderich. The United Kingdom Foreign, Commonwealth and Development Office (FCDO) and the United States Trade and Development Agency (USTDA) are funding the Rural Renewable Energy Project, aiming to bring mini-grid renewable energy connection to approximately 154 locations in Sierra Leone.[8,9,10]

Sierra Leone remains one of the countries with the lowest rates of electrification, with 84 per cent of the country lacking access to electricity in 2018.[11] The country's urban and rural electrification rates were 53 per cent and 6 per cent, respectively, in the same year (Figure 2). The rates of electrification for the main cities as of 2021 are shown in Table 1.

Figure 2. **Electrification Rate in Sierra Leone in 2018 (%)**



Source: IEA[11]

Table 1. **Electrification Rate by City in Sierra Leone in 2021**

City	*Electrification rate (%)*
Freetown	82
Bombali	26
Western Rural Area	25
Bo	18
Kenema	15
Port Loko	12
Kono	8
Bonthe	3
Tonkolili	2
Kailahun	0
Moyamba	0
Pujehun	0
Koinadugu	0
Falaba	0
Karene	0
Kambia	0

Source: Conteh et al.[12]

The electricity in Sierra Leone is generated under the responsibility of the Electricity Generation and Transmission Company (EGTC), which was founded under the National Electricity Act of 2011. The electricity is distributed and supplied by the Government-owned Electricity Distribution and Supply Authority (EDSA), founded in 2014 after the unbundling of the National Power Authority (NPA).[13]

To remedy the instability of the electricity sector in the country, in 2018 the Government, through EDSA, entered into a five-year agreement with the Turkish power ship company Karpowership to supply the capital city of Freetown with electricity. The first power ship, Karadeniz Powership Doğan Bey, was commissioned to supply 50 MW for seven months and 30 MW for five months to Freetown for a period of three years. A second power ship, Karadeniz Powership Göktay Bey, was commissioned and began operations in Cline Town Bay in 2019. Since June 2020, a new agreement signed by EDSA aims to extend the contract with Karpowerhip for five more years for a capacity of 63 MW during the dry season and 23 MW during the wet season. As of 2021, Karpowership supplied Sierra Leone with 80 per cent of its electricity needs.[14]

Electricity tariffs in Sierra Leone are established by EDSA (Table 2).

Table 2. **Average Electricity Tariffs in Sierra Leone**

Consumer type	*Units (kWh)*	*Average electricity tariff (USD/ kWh)*	*GST* (USD)*	*Tariffs incl. GST (USD)*	*Service charge (USD)*
T-1 Residential – social	0–25	0.047	0.007	0.054	0.882
T-1 Residential – normal	>25	0.135	0.020	0.155	N/A
T-2 Commercial	All units	0.157	0.023	0.180	1.186
T-3 Institutions	All units	0.151	0.022	0.173	1.237
T-4 Large energy users	All units	0.159	0.024	0.183	6.353
T-5 Street lighting	All units	0.141	0.021	0.162	2.475
T-2 Welding	All units	0.160	0.024	0.184	3.324

Source: SLEWRC[15]

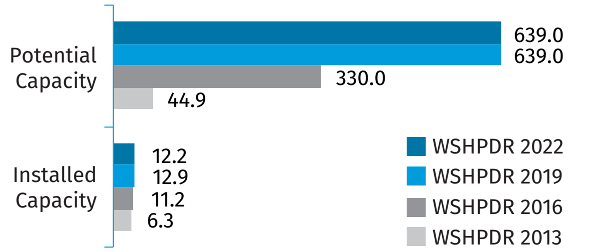
Note: * Goods and services tax (15 per cent)

Sierra Leone is a member country of the Economic Community of West African States (ECOWAS). The ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) aims to support the development of renewable energy sources and energy action plans in the member states. Sierra Leone is also part of the West African Power Pool (WAPP), a regional organization dedicated to fostering greater cooperation in the region's power sector and interconnection among countries to enhance energy security.[16]

SMALL HYDROPOWER OVERVIEW

The definition of small hydropower (SHP) in Sierra Leone follows that of the ECOWAS Small-Scale Hydropower Programme's, which defines SHP as hydropower with installed capacity of up to 30 MW.[16] For the purposes of this chapter, the up to 10 MW definition of SHP will be used. The country's installed capacity for SHP up to 10 MW stood at approximately 12 MW in 2020, coming from eight plants (Table 3).[7] According to the 2017 ECREEE report, Sierra Leone has 639 MW of theoretical potential for SHP up to 10 MW, including 140 MW of pico-, micro- and mini-hydropower and 499 MW of SHP of 1–10 MW capacity.[17] Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity slightly decreased based on the available data, whereas the potential has remained unchanged (Figure 3).

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



Source: AF-Mercados,[7] ECREEE,[17] *WSHPDR 2013*,[18] *WSHPDR 2016*,[19] *WSHPDR 2019*[20]

Note: Data for SHP up to 10 MW.

Table 3. **List of Existing Small Hydropower Plants in Sierra Leone in 2020**

Name	*Capacity (MW)*
Makeni	4.00
Goma	3.00
Charlotte	2.20
Port Loko/Bankasoka	2.20
Makali	0.50
Segbwema	0.15
Panguma	0.09
River n2	0.01
Total	**12.15**

Source: AF-Mercados[7]

There is a planned SHP plant in Sierra Leone, the Moyamba project on the Gbangbaia River, with a potential capacity of 15.4 MW (Table 4). The feasibility study was completed in 2016.[21]

Table 4. **List of Selected Planned Small Hydropower Projects in Sierra Leone**

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Development stage*
Moyamba	Gbangbaia River	15.4	14.8	Feasibility study completed (2016)

Source: ECREEE[21]

RENEWABLE ENERGY POLICY

The Government of Sierra Leone has drafted a number of policies for the creation of an enabling regulatory framework for the development of off-grid renewable energy systems, including the 2009 Energy Policy and the 2016 Energy Efficiency Policy. Specifically, these policies aim to attract private sector investment in the electricity sector, ensure the financial independence and commercial viability of EDSA as well as improve the transparency, predictability and financial viability of the electricity sector.[22]

A major barrier to the penetration of off-grid renewable energy systems in Sierra Leone is the lack of financial inclusion. In 2017, approximately 80 per cent of the population did not have an account with a formal financial institution or a mobile money service provider, compared to an average of 57 per cent in Sub-Saharan Africa. As a way to increase financial inclusion in the country, the Bank of Sierra Leone launched a National Strategy for Financial Inclusion (NSFI) in 2017.[22]

Currently, the Government has several objectives regarding development and renewable energy, which are set forth in the Renewable Energy Policy of Sierra Leone and the National Renewable Energy Action Plan (NREAP) of 2015. Some of the targets include:

- Increasing installed renewable energy capacity, reaching 659 MW by 2020 and 1,229 MW by 2030;
- Increasing access to renewable energy via off-grid solutions including mini-grids;
- Increasing the number of households with solar heating systems.

In order to achieve the set renewable energy goals, the Government of Sierra Leone has been benefiting from financial assistance from the United Kingdom Foreign, Commonwealth and Development Office (FCDO) and the Government of Japan. These countries contributed an estimated USD 700,000 and USD 55,000, respectively, in 2019, for the development of mini-grid electricity systems in Sierra Leone. The United Nations Office for Project Services (UNOPS) contributed to the country's efforts in relation to renewable energy in the form of grants, with an aim of accelerating demand and improving rural energy-reliant economic opportunities and productive use of equipment and services.[23]

Sierra Leone, as a member country of the ECOWAS, is committed to achieving universal electricity access by 2025 through the ECOWAS Regional Renewable Energy Policy for the period of 2015–2030. Under the Sustainable Energy for All (SEforAll) Country Action Agenda, the Government of Sierra Leone also aims to reach a 10 per cent share of the population with access to electricity through off-grid systems powered by renewable energy by 2030.[22]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Precipitation variability is expected to increase in Sierra Leone as a consequence of climate warming. As SHP plants in the country are mostly without seasonal storage possibilities, the down-times of the plants are expected to increase due to extended dry spells. Furthermore, natural hazards are likely to increase with climate change and therefore floods, rock falls and landslides will negatively affect SHP plants.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

SHP development in Sierra Leone is hindered by:

- Funding: There is a lack of sufficient government funding for SHP development;
- Capacity building: There are not enough higher learning institutions in Sierra Leone that focus on teaching the skills necessary to operate and maintain SHP plants. There is also a lack of hydrology departments at local universities which translates into a lack of sufficient local technical experts;
- Manufacturing: All equipment necessary for the operation of an SHP plant needs to be imported as there are no local manufacturers;
- Electricity tariffs: The high electricity tariffs in the country deter private investors;
- Demand: There is low demand for electricity in the country as it suffers from a lack of sufficient financial inclusion for its population. Most citizens would be unable to afford the high electricity tariffs and are not registered with any formal financial institution.[22]

SHP development in Sierra Leone is enabled by:

- External assistance: As solar power development benefits from financial support from the international donors, this is an encouraging sign for future endeavours into the overall renewable energy sector;
- Potential: Sierra Leone has considerable hydropower potential;
- Openness to foreign investment: The country is open to foreign investment for the development of the energy sector.[22,24]

REFERENCES

1. Worldometer (2022). *Sierra Leone Population*. Available at https://www.worldometers.info/world-population/sierra-leone-population/ (Accessed 8 February 2022).
2. African Continental Free Trade Area (AfCFTA) (2022). *Republic of Sierra Leone*. Available at https://afcfta.au.int/en/member-states/sierra-leone#:~:text=With%20a%20land%20area%20of,Atlantic%20Ocean%20to%20the%20west. (Accessed 8 February 2022).
3. United Nations Food and Agriculture Organization (FAO) (2005). *Sierra Leone*. Aquastat database. Available at www.fao.org/nr/water/aquastat/countries_regions (Accessed 8 February 2022).
4. Bangoura, J. S., Sheriff, M. A. & Kamara, M. (2009). *Joint CILSS/FAO/FEWS NET Pre-Harvest Assessment Mission of the 2009/2010 Cropping Season in Sierra Leone*. Freetown. Available at www.agrhymet.ne/PDF/Rapports%20pays/Sierra%20Leone.pdf (Accessed 8 February 2022).
5. World Bank Climate Change Knowledge Portal (n.d.). *Country – Sierra Leone*. Available at https://climateknowledgeportal.worldbank.org/country/sierra-leone/climate-data-historical (Accessed 8 February 2022).
6. Kpaka, G. (2020). *Loss and damage from climate change has pushed Sierra Leoneans far beyond their ability to adapt*. International Institute for Environment and Development (IIED). Available at https://www.iied.org/loss-damage-climate-change-has-pushed-sierra-leoneans-far-beyond-their-ability-adapt (Accessed 8 February 2022).
7. AF-Mercados (2020). *Integrated Resource Plan 2020-2040*. Available at http://www.energy.gov.sl/wp-content/uploads/2021/06/Final-IRP-Sierra-Leone-21122020.pdf (Accessed 24 March 2022).
8. Investing in Sierra Leone (2019). *Sector in Perspective – Energy*. Available at https://www.investinginsierraleone.com/energy/ (Accessed 10 February 2022).
9. Ganie, Z. (2022). *CLSG Transmission Line Brings Energy to Sierra Leone*. ESI Africa. Available at https://www.esi-africa.com/industry-sectors/transmission-and-distribution/clsg-transmission-line-brings-energy-to-sierra-leone/ (Accessed 25 March 2022).
10. Grant, C. (2019). *Investing in Sierra Leone – Energy and Renewable Energy*. Available at https://slideplayer.com/slide/17134121/ (Accessed 24 March 2022).
11. International Energy Agency (IEA), International Renewable Energy Agency (IRENA), United Nations Statistics Division (UNSD), World Bank (WB) & World Health Organization (WHO). (2020). *Tracking SDG 7: The Energy Progress Report 2020*. Available at https://trackingsdg7.esmap.org/downloads (Accessed 15 February 2022)
12. Conteh, F., Takahashi, H., Hemeida, A. M., Krishnan, N., Mikhaylov, M. & Senjyu, T. (2021). *Analysis of Hybrid Grid-Connected Renewable Power Generation for Sustainable Electricity Supply in Sierra Leone*. Available at https://www.mdpi.com/2071-1050/13/20/11435 (Accessed 15 February 2022).
13. Ministry of Energy of the Republic of Sierra Leone (n.d.). *About the Ministry*. Available at http://www.energy.gov.sl/About_Us.html (Accessed 15 February 2022).
14. Karpowership (n.d.). *Project Sierra Leone*. Available at https://karpowership.com/en/sierra-leone (Accessed 15 February 2022).
15. Sierra Leone Electricity and Water Regulatory Commission (SLEWRC) (2020). *SLEWRC 2020 Annual Report*. Available

at https://ewrc.gov.sl/wp-content/uploads/2021/07/SLE-WRC-2020-ANNUAL-REPORT-3.6.21.pdf (Accessed 15 February 2022).

16. Abdulrahman, J. & Paco, D. (2020). *Regional Progress Report on Renewable Energy, Energy Efficiency and Energy Access in ECOWAS region Monitoring year: 2018*. ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE). Available at http://www.ecreee.org/sites/default/files/documents/regional_progress_report_2018_final.pdf (Accessed 10 February 2022).
17. ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) (2017). *Sierra Leone Country Report. GIS Hydropower Resource Mapping and Climate Change Scenarios for the ECOWAS Region*. Available at http://www.ecowrex.org/sites/default/files/country_report_13_sierra_leone.pdf (Accessed 31 March 2022).
18. UNIDO, ICSHP (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
19. UNIDO, ICSHP (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
20. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
21. ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) (n.d). *Moyamba Hydro*. Available at http://www.ecowrex.org/eg/moyamba-hydro (Accessed 31 March 2022).
22. ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) (2019). *Off-Grid Solar Market Assessment & Private Sector Support Facility Design – Sierra Leone Report*. Available at http://www.ecreee.org/sites/default/files/ecreee_rogep_sierra_leone_final_report.pdf (Accessed 17 February 2022).
23. United Nations Office for Project Services (UNOPS) (2021). *Rural Renewable Energy Projects Productive Use Activities*. Available at http://www.energy.gov.sl/wp-content/uploads/2021/07/Fact-sheet_Productive-Use-April-2021-final-2.pdf (Accessed 17 February 2022).
24. International Trade Administration (ITA) (2021). *Sierra Leone Energy Infrastructure*. Available at https://www.trade.gov/country-commercial-guides/sierra-leone-energy-infrastructure (Accessed 18 February 2022).

Togo

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

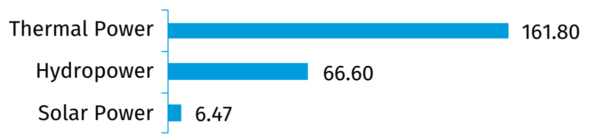
KEY FACTS

Population	8,278,737 (2020)[1]
Area	56,600 km^2 [2]
Topography	The topography of Togo consists of gently rolling hills, shallow valleys and two large alluvial plains. The Atakora Mountain Range cuts through the central part of country with natural forests and savannah landscapes. The northern part of the country, known as the Dry Sudanian Savannah, is home to the Oti River as well as a large national park. The southern regions are characterized by patchworks of cropland and savannahs. The coastal plains, or the fluvial-lagoon zone, is characterized by swamps and lagoons.[3]
Climate	Togo has a tropical climate, with two rainy seasons in the south and one in the north. In the humid south, the rainy seasons occur from mid-April through June and again from mid-September through October. In the north, the rainy season occurs from June to the end of September and the rest of the year enjoys the warm and dry harmattan (dusty wind). Mean annual temperatures in the north vary between 17 °C and 41 °C, while the south is more stable with an average annual temperature of 27 °C.[4,5]
Climate Change	Togo is affected by global warming. The mean annual temperature has increased by 1.1 °C since 1960, at an average rate of 0.24 °C per decade. The number of hot days between 1960 and 2003 has increased by 16 per cent and heatwaves have become more common. Precipitation in Togo has been decreasing at an average of 2.4 per cent per decade and no increase in heavy rainfall events have been observed.[5]
Rain Pattern	The southern coastal zone receives approximately 890 mm of annual precipitation and is the driest region. The highest amount of precipitation in the country, 1,800 mm, is received by the south-western region. In the north, precipitation averages 1,150 mm in the rainy season. The mean annual precipitation in Togo is 1,176.5 mm.[4,5]
Hydrology	Togo is endowed with many lagoons, the largest of which is Lake Togo which is also the country's largest body of inland water. More than half the length of the country is traversed by the Mono River, which flows from north to south before flowing into the Gulf of Guinea. The torrential river's intake fluctuates greatly, from an annual average of 99.6 m^3/s to 4.8 m^3/s in the dry season. The Oti River, in the north, drains into the Volta River, which flows to the north-west.[6]

ELECTRICITY SECTOR OVERVIEW

The main sources of electricity in Togo are thermal power and hydropower. In 2019, thermal power accounted for 67 per cent of total production, which amounted to 647 GWh, and hydropower accounted for almost 32 per cent. Production from solar power plants accounted for 9 GWh, or approximately 1 per cent of the total electricity produced (Figure 1).[7]

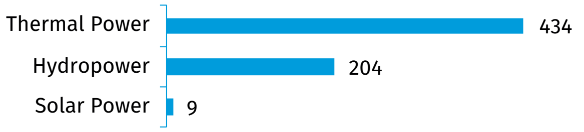
Figure 1. **Annual Electricity Generation by Source in Togo in 2019 (GWh)**



Source: IRENA[7]

In Togo, electricity is supplied mainly through the interconnected Electricity Community of Benin (CEB) and the local power system of the state-owned utility Electricity Energy Company of Togo (CEET). CEB consists of a 20 MW gas turbine in Lomé and a 65 MW hydropower plant in Nangbeto for a combined installed capacity of 85 MW. CEET owns a system of 143.4 MW of installed capacity, including a 1.6 MW hydropower plant in Kpimé and 100 MW (LFO, HFO, gas) of capacity owned by the CEET and exploited by the independent power producer (IPP) Contour Global Togo S.A under a licence. The isolated grid contributes an additional 6.47 MW of installed solar capacity. The total installed electricity capacity in 2020 was thus 234.87 MW, of which thermal power, hydropower and solar power accounted for approximately 69 per cent, 28 per cent and 3 per cent, respectively (Figure 2).[8]

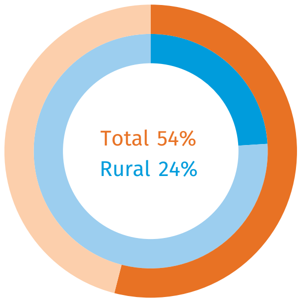
Figure 2. **Installed Electricity Capacity by Source in Togo in 2020 (MW)**



Source: ARSE[8]

In 2020, the total electrification rate in Togo was 54 per cent, with 24 per cent rural access (Figure 3).[9,10]

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



Source: World Bank[9,10]

Table 1. **Electricity Consumption by Sources in Togo in 2020**

Consumer category	*Electricity consumed (%)*
Commercial and industrial sector	57.4
Residential sector	32.6
Administration and public Services	10.0

Source: ARSE[8]

In Togo, the electricity sector is regulated by the Regulation Authority of the Electricity Sector (ARSE), which is also responsible for advising the Ministry of Mines and Energy on electricity tariffs, among other duties. Since 2011, the electricity tariffs on the Togolese territory are fixed through the ministerial decree No. 019/MME/MEF/MCDAT/MPR-PDAT/MCPSP of 2010. In 2020, the tariffs ranged from 0.17 USD/kWh to 0.20 USD/kWh (Table 2).[8]

Table 2. **Electricity Tariffs in Togo in 2020**

Customer category	*Tariff, incl. taxes (USD/kWh)*
Low voltage	0.20
Medium voltage	0.17
High voltage	0.19

Source: ARSE[8]

CEET is the Government-owned utility responsible for the distribution and transmission of electricity produced in Togo both through its own power plants, power plants exploited by IPPs and shared plants with CEB. CEB is a bi-national entity established in 1968 to provide generation and transmission for both Togo and Benin and had, until 2003, a monopoly on the production and distribution of electricity for both countries.[8]

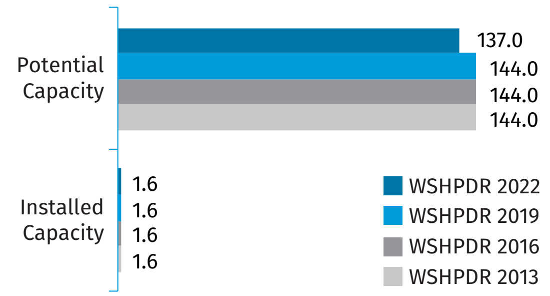
In addition to being half of the interconnected Benin–Togo grid, Togo is also a member of the Economic Community of West African States (ECOWAS) energy framework and the West Africa Power Pool (WAPP).[11]

SMALL HYDROPOWER SECTOR OVERVIEW

There is no official definition of small hydropower (SHP) in Togo. For the purpose of this chapter, SHP will include hydropower plants with an installed capacity of up to 10 MW. It should be noted that in the ECOWAS region, which Togo is part of, many countries use the ECOWAS definition of 1 MW to 30 MW of installed capacity for SHP.

There is one SHP plant in Togo, located in Kpimé, with an installed capacity of 1.6 MW. The identified SHP potential is approximately 137 MW. This identified potential differs from the potential reported in the *World Small Hydropower Development Report (WSHPDR) 2019* due to later studies conducted by the Government of Togo as indicated in the Baseline Report on Existing and Potential Small-Scale hydropower systems in the ECOWAS Region.[12] At the same time, the installed SHP capacity remained unchanged (Figure 4).

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



Source: ECREEE,[12] *WSHPDR 2013*,[13] *WSHPDR 2016*,[14] *WSHPDR 2019*[15]

The Baseline Report on Existing and Potential Small-Scale Hydropower Systems in the ECOWAS Region was prepared by the ECOWAS for Renewable Energy and Energy Efficiency (ECREEE) in cooperation with the United Nations Industrial Development Organization (UNIDO), the Energy Sector Management Assistance Programme (ESMAP) and the Government of Liberia. The report explored the SHP potential of ECOWAS member-states and highlighted the SHP potential of Togo, under both the ECOWAS definition of SHP (up to 30 MW) and the international definition (up to 10 MW). The former definition produced an SHP potential of 206 MW and the latter 137 MW.[12]

There are numerous rivers in Togo and the Government has identified seven sites for the development of SHP with a combined potential installed capacity of 40 MW (Table 3).[16]

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

Site Name	*Capacity (MW)*
Danyi-Konda	10
Kpéssi	8
Tomégbé Akloa	8
Baghan	6
Landa-Pozanda	4
Amou Oblo	2
Glei	2

Source: Kansongue et al.[16]

RENEWABLE ENERGY POLICY

As a member of ECOWAS, Togo adopted the National Renewable Energy Policy (NREP) and the National Energy Efficiency Policy (NEEP) that all 15 member-states adopted in 2012. In 2015, The Government of Togo combined the NREP and NEEP for a cohesive National Renewable Energy Action Plan (NREAP 2015–2020–2030), which outlines the legal framework for electricity generation from renewable energy sources, both for own and commercial use. The NREAP addresses all sources of renewable energy, including wind power, solar power, thermal power, tidal power and hydropower and defines incentives for developers of renewable energy projects, such as tax incentives. The policy was developed by the Ministry of Mines and Energy in cooperation with CEET, the Togolese Rural Electrification and Renewable Energy Agency (AT2ER), ARSE, ECREEE, the German Agency for International Cooperation (GIZ) and the Governments of Austria and Spain.[17]

In the NREAP, the Government of Togo has several objectives regarding the development of renewable energy. Some of the targets include:

- Develop solar power capacity and increase its share in the final energy consumption to 10 per cent by 2030;
- Develop SHP in rural areas and ensure minimal environmental impact from SHP construction and maintenance;
- Attract private sector investment in hydropower;
- Develop bioenergy and promote consumption, particularly in rural areas, as an alternative source of energy;
- Develop a comprehensive database on renewable energy potential in Togo.[17]

The targets set in the NREAP were formulated to fulfil the goals of universal electrification and increase in installed renewable energy capacity to 364 MW by 2030. In addition to the specific targets, the Government of Togo aims to promote education and awareness of environmental protection and the importance of renewable energy. The Government of Togo also aims to involve local populations in all aspects of renewable energy development, including rural population involvement in the construction and development of SHP.[17]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

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

- Decree No. 63-12 (1963) on the creation of the Electricity Energy Company of Togo;
- Law No. 2000-012 (2000) on the organization and function of ARSE;
- Decree No. 2019-021 (2019) that sets the licensing for production, transmission and commercialization of renewable energy.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Precipitation variability is expected to increase in Togo as a consequence of climate warming. As the only SHP plant in the country is mostly without seasonal storage possibilities, the down-times of the plant are increasing due to extended dry spells. Furthermore, natural hazards are likely to increase with climate change and, therefore, floods, rock falls and landslides will negatively affect existing and prospective SHP plants.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The development of SHP in Togo is mainly hampered by:

- Non-liberalized energy sector might deter prospective investors;
- Lack of sufficient and relevant rules and regulations within the energy sector such as standardized power purchase agreements and power purchase tariffs;
- Higher initial costs for hydropower investment than diesel generators;
- Lack of sufficient international funding for SHP driven by the lack of successful SHP projects that would inspire confidence in investors;
- Lack of manufacturing of equipment essential for SHP construction and maintenance in the country.

Enablers for SHP development in Togo include:

- Specific mention of SHP and its importance for rural electrification in national renewable energy strategy documents such as NREP and NREE;
- The commitment by the Government to exploit the country's SHP potential. Plans to build SHP plants at Danyi-Konda, Baghan and Landa-Pozanda were in mo-

tion as of 2022;
- Significant potential for SHP development due to numerous rivers found in the country;
- Plans to promote private sector investment in SHP as outlined in the country's national renewable energy strategy.

REFERENCES

1. World Bank (2020). *Population, Total – Togo*. Available at https://data.worldbank.org/indicator/SP.POP.TOTL?locations=TG (Accessed 18 May 2022).
2. Encyclopaedia Britannica (2022). *Togo: Facts & Stats*. Available at https://www.britannica.com/facts/Togo (Accessed 18 May 2022).
3. U.S. Geological Survey (USGS) (n.d.). *Ecoregions and Topography of Togo*. Available at https://eros.usgs.gov/westafrica/ecoregions-and-topography/ecoregions-and-topography-togo#:~:text=With%20the%20exception%20of%20the,central%20part%20of%20the%20country (Accessed 18 May 2022).
4. Encyclopaedia Britannica (2022). *Togo*. Available at https://www.britannica.com/place/Togo (Accessed 18 May 2022).
5. Climate Change Knowledge Portal (2020). *Country – Togo*. Available at https://climateknowledgeportal.worldbank.org/country/togo/climate-data-historical#:~:text=Togo's%20climate%20varies%20from%20tropical,%C2%B0C%20%2D%2041%C2%B0C. (Accessed 18 May 2022).
6. Economic Community of West African States, Centre for Renewable Energy and Energy Efficiency (ECREEE) (2012). *Baseline Report on Small-Scale Hydropower in the ECOWAS Region*. Available at http://www.ecreee.org/sites/default/files/documents/basic_page/ecowas-unido_sshp_baseline_report.pdf (Accessed 18 May 2022).
7. International Renewable Energy Agency (IRENA) (2021). *Energy Profile: Togo*. Available at https://www.irena.org/IRENADocuments/Statistical_Profiles/Africa/Togo_Africa_RE_SP.pdf (Accessed 18 May 2022).
8. Regulation Authority of the Electricity Sector (ARSE) (2020). *Rapport d'Activités 2020*. Available at http://www.arse.tg/wp-content/uploads/2022/03/Rapport_Annuel_ARSE_2020_VF.pdf [in French] (Accessed 19 May 2022).
9. World Bank (2020). *Access to Electricity (% of Population) – Togo*. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=TG (Accessed 19 May 2022).
10. World Bank (2020). *Access to Electricity, Rural (% of Rural Population)*. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS?locations=TG (Accessed 19 May 2022).
11. West African Power Pool (n.d.). *Creation of the WAPP*. Available at https://www.ecowapp.org/en/content/creation-wapp (Accessed 19 May 2022).
12. ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) (2012). *Baseline Report on Existing and Potential Small-scale Hydropower Systems in the ECOWAS Region*. Available at http://www.ecreee.org/sites/default/files/documents/basic_page/ecowas-unido_sshp_baseline_report.pdf (Accessed 19 May 2022).
13. UNIDO, ICSHP (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organisation; International Center on Small Hydro Power. Available at www.unido.org/WSHPDR.
14. UNIDO, ICSHP (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
15. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
16. Kansongue, N., NJuguna, J. & Vertigans, S. (2022). *An assessment of renewable energy development in energy mix for Togo*. Available at https://www.tandfonline.com/doi/pdf/10.1080/14786451.2021.2023150 (Accessed 19 May 2022).
17. Republic of Togo (2015). *Plan d'Action National des Energies Renouvelables (PANER)*. Available at https://www.se4all-africa.org/fileadmin/uploads/se4all/Documents/Country_PANER/Togo_Plan_d_Actions_National_des_Energies_Renouvelables.pdf [in French] (Accessed 20 May 2022).

Contributing organizations

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