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World Small Hydropower Development Report 2019

Africa

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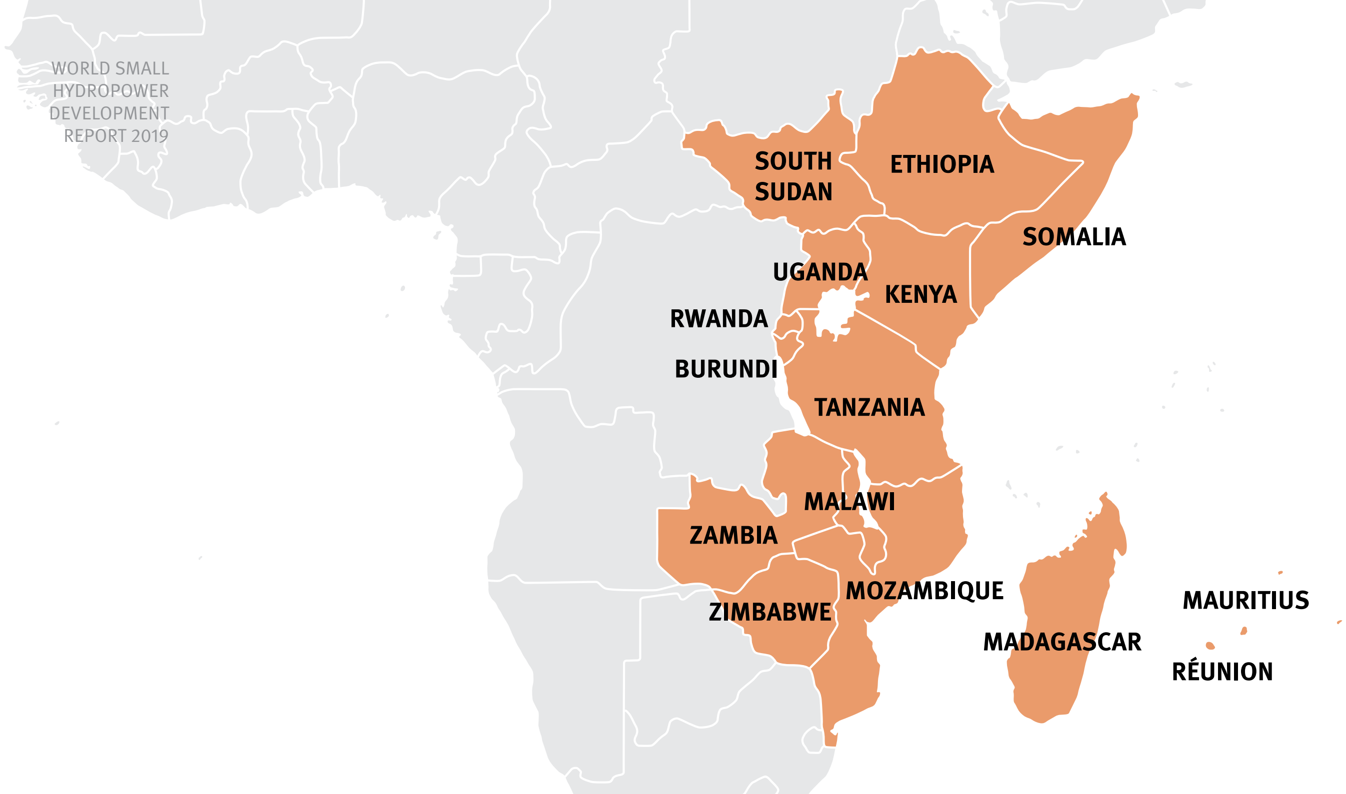


1.1 Eastern Africa

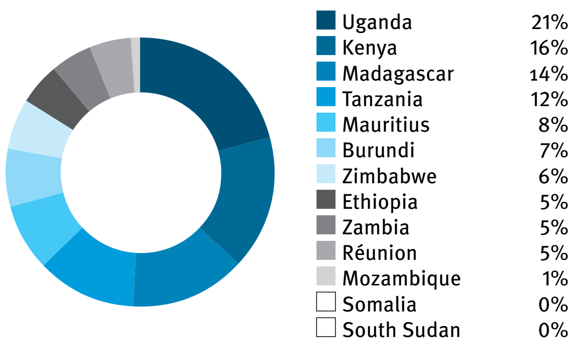
Mohamedain E. Seif Elnasr, Association of Energy Regulators of the Common Market for Eastern and Southern Africa (COMESA)

Introduction to the region

The Eastern Africa region comprises 22 countries and territories. This report focuses on 15 countries from the region. They are Burundi, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, Somalia, South Sudan, Uganda, the United Republic of Tanzania, Zambia and Zimbabwe, as well as Réunion, an overseas department of France. An overview of the selected countries of Eastern Africa is presented in Table 1.

The climate and topography of the region vary widely, from humid tropical to sub-tropical savanna and plateaus to arid desert. The Great Rift Valley traverses the region and is home to the two highest mountains in Africa, Mount Kilimanjaro and Mount Kenya. Burundi, Kenya, the United Republic of Tanzania and Uganda, together with the Democratic Republic of the Congo, form the African Great Lakes region and are home to some of the largest and deepest freshwater lakes in the world. All the lakes in this area combined hold roughly one quarter of the planet's freshwater. The lakes drain into the region's major river systems, including the White Nile, the Congo River, and the Shire and Zambezi rivers.

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



Source: *WSHPDR 2019* [3]

Note: Does not include countries for which data on capacity up to 10 MW is not available. The use of the term 'country' does not imply an opinion on the legal status of any country or territory.

Some areas within the region are mountainous and have high rainfall, in some cases upwards of 2,000 mm annually, leading to significant hydropower potential, both for large- and small-scale hydropower. Thus, the region's small hydropower (SHP) potential of up to 10 MW is estimated to be at almost 7,000 MW (Table 2). Uganda accounts for the greatest share of the installed SHP capacity up to 10 MW in the region (Figure 1).

All countries listed in this report, apart from Mozambique, Réunion, South Sudan and the United Republic of Tanzania, are Member States of the Common Market for Eastern and Southern Africa (COMESA). COMESA is a free trade and customs union area that comprises 21 countries and is one of the building blocks of the African Union. Additionally, six countries in the African Great Lakes region (Burundi, Kenya, Rwanda, South Sudan, the United Republic of Tanzania and Uganda) are members of the East African Community (EAC), which is an intergovernmental organization and another building block of the African Union.

Regarding the power sector, there is one existing power pool: The Eastern Africa Power Pool (EAPP). The EAPP is mandated to develop energy resources in the region and ease the access of all countries in the Eastern Africa region to electricity power supply through the regional power interconnections.[9] Countries in the context of this report which are members of the EAPP include Burundi, Ethiopia, Kenya, Rwanda, the United Republic of Tanzania and Uganda.

Table 1.
Overview of countries in Eastern Africa

Country	*Total population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Burundi	10.5	87	8	74	174	34	100
Ethiopia	99.8	80	43	4,232	16,576	3,814	N/A
Kenya	51	73	73	2,351	10,205	705	3,341
Madagascar	24.9	63	15	813	1,651	163	N/A
Malawi	19.2	85	12	508	1,855	352	N/A
Mauritius	1.7	59	99	826	3,157	N/A	90
Mozambique	29.7	65	24	2,789	10,586	2,134	8,285
Réunion	0.9	N/A	99	843	2,986	133	422
Rwanda	12.2	83	46	218	673	98	N/A
Somalia	14.7	56	30	103	N/A	0	0
South Sudan	12.3	81	9	82	N/A	0	0
Tanzania	51.6	67	33	1,370	6,362	573	N/A
Uganda	37.7	77	15	943	3,874	712	3,457
Zambia	16.4	57	31	2,827	11,695	2,566	11,025
Zimbabwe	16.5	68	42	2,215	9,394	930	4,989
Total	**399.1**	-	-	**20,194**	**79,188**	**12,214**	**31,709**

Source: *WSHPDR 2016*,[2] *WSHPDR 2019*,[3] WB,[4,5] NISR[6]

Small hydropower definition

The definition of SHP varies throughout the region, however, many countries accept the International Center on Small Hydro Power (ICSHP) and COMESA classification of up to 10 MW. Zimbabwe has the highest upper limit for SHP at 30 MW, while the lowest is Burundi at 1 MW. An overview of the countries' definitions of SHP is available in Table 2.

Regional small hydropower overview and renewable energy policy

The quest for an adequate, quality, cost-effective, clean and affordable supply of energy stimulates most countries to consider the role that renewable energy should play in the diversification of their energy matrices. SHP has been identified by many countries of the region as a technology that can enhance energy security, accessibility, reliability and affordability and, thus, support development and sustainable inclusive economic growth. Many countries in the region have manged to put in place enabling policy and regulatory regimes, which have assisted them with attracting investment in renewable energy development, including SHP, and created the conditions for the operation of independent power producers (IPPs).

The total installed capacity of SHP in the region is 275.5 MW (Table 2), indicating that only 4 per cent of known SHP potential has been developed (Figure 2). Compared to the findings of the *World Small Hydropower Development Report (WSHPDR) 2016*, the installed capacity of SHP up to 10 MW in the Eastern Africa region increased by 28 per cent (Figure 3). Across countries, the most significant increase has been observed in Uganda at 17.4 MW.

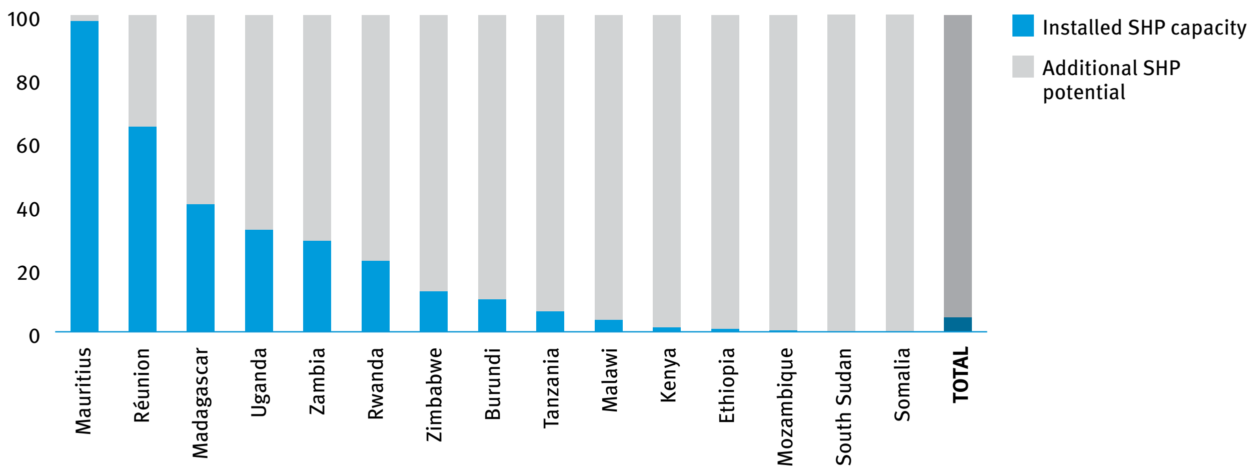
Table 2.
Small hydropower capacities in Eastern Africa (local and ICSHP definition) (MW)

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed (<10 MW)*	*Potential (<10 MW)*
Burundi	up to 1	3.1	30.5	15.8	61.0
Ethiopia	up to 10	12.9	1,500	12.9	1,500
Kenya	up to 10	39.4	3,000	39.4	3,000
Madagascar	-	-	-	33.0	82.0
Malawi	up to 5	5.6	150.0	5.6*	150.0*
Mauritius	-	-	-	19.3	19.7
Mozambique	up to 25	19.4	N/A	3.4	1,000
Réunion	up to 10	11.0	17.0	11.0	17.0
Rwanda	up to 5	24.8	111.1	24.8*	111.1*
Somalia	-	-	-	0.0	4.6
South Sudan	-	-	-	0.0	24.7
Tanzania	up to 10	30.4	480.0	30.4	480.0
Uganda	up to 20	82.8	258.0	51.8	200.0
Zambia	up to 20	39.7	138.7	12.9	62.0
Zimbabwe	up to 30	30.2	N/A	15.2	120.0
Total		-	-	**276**	**6,832**

Source: *WSHPDR 2019*[3]

Note: *Data as per the local definition of SHP.

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



Source: *WSHPDR 2019*[3]

Note: This Figure illustrates data for local SHP definitions or the definition of up to 10 MW in case of the absence of an official local definition. For Zimbabwe and Mozambique, the data is presented for the SHP definition of up to 10 MW due to the absence of data on potential capacity according to the local definitions.

An overview of small hydropower for selected countries of Eastern Africa is outlined below. The information used in this section is extracted from the country profiles, which provide detailed information on small hydropower capacity and potential, among other energy-related information.

Following the local definition of 1 MW, **Burundi** has a small hydropower potential of approximately 30.5 MW and an installed capacity of 3.1 MW. However, with regards to the standard classification of SHP as plants up to 10 MW, the installed capacity is 15.8 MW. The potential of SHP up to 10 MW, as determined based on planned SHP projects, is 61.0 MW. Compared to the *WSHPDR 2016*, both the installed and potential capacities have remained unchanged.

The installed capacity of SHP up to 10 MW in **Ethiopia** is 12.9 MW. However, the potential is estimated to be 1,500 MW, indicating that less than 1 per cent has been developed. Since the publication of the *WSHPDR 2016* the installed capacity has more than doubled, while estimated potential has not changed.

It is argued that **Kenya** has one of the best energy mixes in the region, in the sense that the country's total installed capacity includes hydropower (both small and large), geothermal power, fossil fuels and bagasse, among others. Although the potential for SHP development (up to 10 MW) in Kenya is estimated at 3,000 MW, the installed capacity stands at only 39.4 MW. Compared to the *WSHPDR 2016*, potential capacity has remained the same, while the installed capacity has increased by 22 per cent. The latest addition was the Gura hydropower station in 2017, a SHP plant with an installed capacity of 5.8 MW.

Madagascar is endowed with significant potential for SHP. As such, the Government of Madagascar is seeking the contribution of national and international private sector technical and financial partners to finance a significant portion of the investments planned for the development of the identified small hydropower projects. In 2017, the combined installed capacity of SHP plants up to 10 MW was approximately 33 MW. In comparison to the *WSHPDR 2016*, the installed capacity has increased by 6.5 per cent.

The total installed capacity of SHP plants under 5 MW in **Malawi** is approximately 5.6 MW, with an additional proven potential of at least 7.7 MW and a theoretical estimated potential of 150 MW. This indicates that approximately 5 per cent of the country's known potential has been developed. Compared to data from the *WSHPDR 2016*, the installed capacity has remained unchanged.

The installed capacity of SHP up to 10 MW in **Mauritius**, which has 10 existing plants, was 19.34 MW in 2018. This indicates an increase of 10 MW compared to the *WSHPDR 2016*, which can be attributed to the availability of updated data. There are no existing studies to give an accurate estimate of the SHP potential in the country. A new SHP station at the Bagatelle Dam with a capacity of 350 kW has been commissioned that, once it is fully operational, will bring the country's total installed capacity up to at least 19.69 MW.

The total installed capacity of SHP plants up to 10 MW in **Mozambique** in 2016 was 3.37 MW, while available capacity stood at only 2.77 MW. Compared to the *WSHPDR 2016*, the installed capacity up to 10 MW has increased by 1.1 MW, while the potential capacity has remained unchanged. It should be noted that under the Mozambican definition of SHP as plants with an installed capacity up to 25 MW, the 16 MW Corumana hydropower plant would be included, bringing the installed capacity of SHP to 19.37 MW.

The total installed capacity of SHP up to 10 MW in **Réunion** is approximately 11 MW. The country has only 6 MW of untapped potential, making its SHP total potential 17 MW, of which 65 per cent has been developed. Compared to the *WSHPDR 2016*, the installed capacity remained unchanged, as no new projects were developed, while potential capacity decreased due to the availability of updated data.

Rwanda defines SHP as plants with an installed capacity up to 5 MW. In this regard, the current installed capacity of SHP in Rwanda is 24.8 MW, with an additional potential of at least 86.4 MW (based on the projects under development and identified sites). This indicates that only 22 per cent of the country's total potential has been developed. In comparison to the data from the *WSHPDR 2016*, the installed and potential capacities have increased by 7 and 131 per cent, respectively.

Currently, there are no operational hydropower plants in **Somalia**, however, there is a potential to rehabilitate the Fanoole hydropower plant that was operational prior to the civil war. The rehabilitation of the plant would bring the country's SHP capacity up to 4.6 MW.

South Sudan is rich in hydropower resources, both large- and small-scale, which remain untapped. South Sudan has identified several SHP sites with a combined capacity of 24.7 MW and has finalized feasibility studies. These sites are pending available financing.

The current SHP installed capacity up to 10 MW in the **United Republic of Tanzania** is estimated at 30.4 MW, which includes isolated and unconnected plants. The country's total estimated potential is 480 MW, indicating that approximately 6 per cent of the potential has been developed. Compared to the data from the *WSHPDR 2016*, both the installed and potential capacities have increased by 20 per cent. Potential capacity has been increasing due to new studies identifying new sites suitable for small hydropower development.

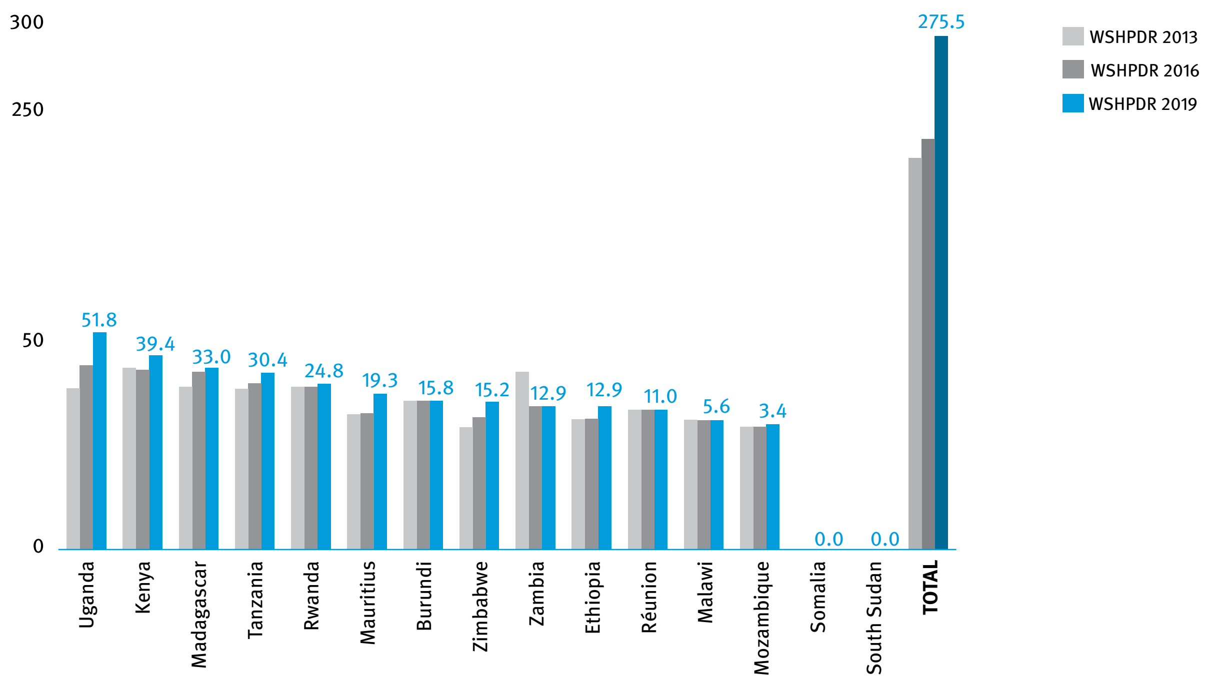
The total installed capacity of SHP plants up to 20 MW in operation in **Uganda** is 82.8 MW, while the potential is estimated at approximately 258 MW, indicating that approximately 32 per cent of this potential capacity up to 20 MW has been developed. The installed capacity of SHP plants up to 10 MW is 51.8 MW and potential capacity is approximately 200 MW, indicating that 26 per cent of the potential capacity up to 10 MW has been developed. Compared to the *WSHPDR 2016*, the potential of SHP plants up to 10 MW has remained unchanged, while the installed capacity has increased by 51 per cent as a result of the commissioning of four new plants (Ishasha, Rwimi, Siti 1 and Kisilzi hydropower plants).

As of 2016, the total installed capacity for micro- and SHP plants in **Zambia** stood at 39.7 MW, based on the country's definition of SHP up to 20 MW. Zambia is currently rehabilitating and upgrading three SHP plants: the Chishimba hydropower plant is being rehabilitated and upgraded from 6 MW to 10 MW; the Lusiwasi hydropower plant is being replaced by new plants upstream and downstream with capacities of 12 MW and 86 MW; and the Musonda hydropower plant is being rehabilitated and upgraded from 5 MW to 10 MW.

In **Zimbabwe**, the installed capacity of SHP up to 10 MW reached 15.2 MW by 2017, mainly from run-of-river schemes in the Eastern Highlands. The total capacity under development is 27.3 MW. Most of the micro-scale schemes were installed by Practical Action and Oxfam as donations, while the SHP schemes which are connected to the grid were completed by IPPs such as Nyangani Renewable Energy (NRE) and Kupinga Hydro. Many more IPPs were licensed by the Zimbabwe Energy Regulatory Authority for different sites and are at different stages of development.

Feed-in tariffs (FIT) have been introduced in Kenya, Mauritius, Réunion, Rwanda, the United Republic of Tanzania and Uganda. The Zimbabwe Energy Regulatory Authority developed some FITs, which have not yet been approved by the Government of Zimbabwe. The Ethiopian Energy Authority is currently developing a FIT scheme, while the Government of Zambia initiated the introduction of a FIT programme and the Government of Malawi has set the objective to introduce such tariffs.

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



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

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

Barriers to small hydropower development

It has been established that there are several barriers which hinder the development of renewable energy, including SHP, in Eastern Africa. While many Governments have been exerting efforts to adopt policies encouraging inclusive and sustainable development strategies, the financial aspect remains the major constraint impeding progress in the development of SHP. In addition, project costs can be higher in the region due to the lack of data on resources and undeveloped renewable energy industry. This includes the lack of local technology, as well as skilled workers to install, operate and maintain SHP plants.

Another factor hindering SHP development in **Burundi** is the legal and institutional framework which is unfavourable for investors. The exploitation of small-scale hydropower in **Kenya** is impeded by long procedures and inconsistency in the approval of power purchase agreements. **Madagascar** lacks a well-structured renewable energy development plan and an evaluation monitoring system.

Similarly, in **Zambia**, there is a lack of a comprehensive energy policy to deal with the requirements of private plants interfacing with the national grid. Additionally, the cost of transporting electricity generated from renewable energy sources to the country's consumption centres affects the bankability of projects considering that suitable SHP potential is mainly located in remote areas. In **Mozambique**, SHP development is hindered by the lack of a strategy defining the government's investment plans for hydropower plants and local technologies. In addition, the country's market remains underdeveloped.

In **Ethiopia**, additional barriers include decentralized energy production and management, as well as limited participation of the Government in the development of renewable energy technologies. While the Government has introduced FITs, rates remain relatively low, resulting in a loss of interest among local and foreign investors.

In **Rwanda**, many of the challenges that the SHP sector faces are linked to challenges for the electricity sector in general. These include limited demand, high tariffs, low energy potential, insufficient and unreliable electricity supply, limited access of low-income households to electricity and limited funds for programme development. In the **United Republic of Tanzania**, the majority of the rural population is not able to afford the initial connection costs and monthly bills. In addition, awareness of SHP remains limited.

The rural population of **Malawi** often cannot afford paying the upfront costs of wiring, inspection and connection. There is also a lack of information and awareness about SHP among the population. Moreover, the hydropower sector is significantly affected by deforestation, which degrades catchment areas, leading to siltation and reduced base flows in rivers, as well as extreme weather events such as droughts, floods, termite attacks and natural rotting of wood structures, bush fires and vandalism. The SHP sector of **Zimbabwe** is affected by extreme weather conditions.

The flat topography of **Mauritius**, limited catchment areas and seasonal fluctuations in rainfall, which are further exacerbated by climate change, do not favour hydropower development. There is also a lack of proper infrastructure to access potential hydropower sites.

Réunion also experiences climatic variations and destruction, coupled with volcanic activity, which pose risk to SHP development. The island is also classified as a World Heritage Site, leading to stringent environmental impact assessments and a high cost of land.

In **Somalia**, there are security concerns surrounding regional terrorist groups and the potential for infrastructure to be targeted. There is also an absence of an interconnected grid system with enough capacity to support the transmission and usage of electricity to both urban and rural populations, as well as limited interconnection with regional power pools.

South Sudan has also been heavily affected by war. As a result, relevant laws for renewable energy have not been enacted, strategies for the renewable energy sector have not been adopted, the required infrastructure has not been developed and there has been high population displacement. War has also made access to feasibility sites difficult.

In **Uganda**, there is an infrastructure gap in the generation, transmission and distribution of electricity. The land acquisition process is bureaucratic, complex, slow and affects overall project costs.

Nonetheless, the major barriers to SHP development in the region can be addressed through a range of interventions, one of which is the establishment of regional and national renewable energy policies to include appropriate incentives for investment.

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Burundi

1.1.1

Jeremie Sinzinkayo, Agency for Regulation of Water, Electricity and Mines

Key facts

Population	10,524,117 [1]
Area	27,834 km[2]
Climate	Burundi has an equatorial climate. Temperatures near Lake Tanganyika and the Ruzizi River Plain are high, ranging between 27 °C and 32 °C during the day and between 21 °C and 24 °C at night. The central plateau, however, enjoys a cooler climate, with temperatures ranging from 18 °C to 22 °C, while the high mountainous area in the west experiences the coolest temperatures, ranging between 12 °C and 16 °C. The capital, Bujumbura, located to the west of the north-eastern shore of Lake Tanganyika, experiences an average annual temperature of 23 °C.[2]
Topography	Burundi is predominantly characterized by plateaus and mountains. The western part of the country is composed of mountain ranges running from north to south, with the highest point being located at Mount Heha at 2,670 metres above sea level. The only plains in Burundi exist along the Ruzizi River, north of Lake Tanganyika, forming the western border with the Democratic Republic of the Congo.[2]
Rain pattern	There are two seasons in Burundi: a wet season lasting from October to April and a dry season lasting from May to September. April usually has the most rainfall, while the driest month is usually July. The average annual rainfall is 848 mm.[3]
Hydrology	Burundi has four major rivers: the Kanyaru, Malagarasi, Rusizi and Ruvubu. It also has three major lakes: Cohoha, Rweru and Tanganyika.[4] The rivers of Burundi, apart from being sources of water for the country, are also utilized for the generation of hydroelectric power.[5]

Electricity sector overview

As of the end of 2017, Burundi had a total installed generation capacity of approximately 74 MW, comprised of 33.84 MW from hydropower and 40.5 MW from diesel-fired plants, including a 30 MW diesel power plant that was extended in 2017 to bring an immediate emergency electricity supply to Bujumbura (Figure 1).[6,7,13,17,18] An additional 16.7 MW is imported from the hydropower complex located on the Ruzizi River in the Democratic Republic of the Congo, which is shared between Rwanda, the Democratic Republic of the Congo and Burundi.[19] There are also a number of projects under development, including a 7.5 MW solar plant in the Mubuga, Gitega province, the 49 MW Jiji-Murembwe hydropower pant, the 10.4 MW Mpanda hydropower plant, the 20 MW Kaburantwa hydropower plant and the 12 MW Kagunuzi hydropower plant.[20,21]

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

Source: IEA,[6] Gigawatt Global,[7,17] Ministry of Energy and Mines,[13] REGIDESO[18]

In 2016, electricity generation in Burundi totalled 167 GWh, with hydropower accounting for 86 per cent and thermal power plants for the remaining 14 per cent. However, in 2017, total electricity generation was 174 GWh, with thermal power plants accounting for 43 per cent and hydropower plants for 57 per cent (Figure 2).[22] Such a dramatic change in the share of sources in the country's electricity generation was caused by the introduction of new thermal power capacities and unfavourable hydraulic conditions that year. An additional 85 GWh of electricity was imported from the Ruzizi complex in 2017, compared to approximately 120 GWh in 2016.[22]

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

Source: ISTEEBU[22]

The national electrification rate in 2016 stood at 7.6 per cent, with 1.7 per cent access to electricity in rural areas and 50 per cent in urban areas.[1] Bujumbura accounts for approximately 80—85 per cent of total electricity consumption in the country.[22] Due to frequent blackouts, many households and business owners purchase backup generators. The resultant costs are often appropriated directly from business profits, thus reducing business viability in domestic, regional and international market competition.[9] Power cuts, therefore, are one of the main obstacles to economic growth in the country. The country's electricity sector is traditionally state-owned. Structural adjustments and privatization in the sector had been commenced in 1989 but the civil and political conflicts curtailed the process.[8] Electricity generation and supply in Burundi is managed and administrated by two primary organizations and one sub-government agency. The first organization, Directorate for Production and Distribution of Water and Electricity (REGIDESO), is a state-owned company that operates and controls all thermal power plants and 96.5 per cent of the installed hydropower capacity.[8,9] REGIDESO is also responsible for power and water distribution in urban and rural areas.[8]

The Burundian Agency for Rural Electrification (ABER), a government agency and customer of REGIDESO, is responsible for electrification of rural areas. The second primary organization is the International Society for Electricity in the Great Lakes Region (SINELAC), which is a multinational organization comprising the Democratic Republic of the Congo, Burundi and Rwanda. SINELAC is responsible for developing international electricity projects, which include the Ruzizi hydropower plant located in the Democratic Republic of the Congo and the Ruzizi II, which is shared equally between Burundi, the Democratic Republic of the Congo and Rwanda.[10] SINELAC is planning to refurbish the existing plants of the cascade and to add two new plants, Ruzizi III and Ruzizi IV, with a capacity of 147 MW and 287 MW, respectively, which will bring the total installed capacity of the cascade to 500 MW.[24]

The electrical transmission system in Burundi is made up of 750 km of high-voltage lines (110 kV) and medium-voltage lines (30 kV), over which REGIDESO has exclusive responsibility.[10] The transmission network was set up before the civil wars and, as a result, is extremely outdated and requires urgent refurbishment. In 2016, the network's electricity losses were estimated at 27.5 per cent.[23] Burundi is a member of the Eastern Africa Power Pool (EAPP) which aims for the electrical interconnectivity between all countries in the Eastern African region. This linkage would allow for more flexible import and export of electricity between countries in the region. However, the current transmission network in Burundi is not adequate for an interconnected system. The current 110 kV lines would need to be replaced with 220 kV lines in order for Burundi to effectively connect its national grid to the regional power lines of the EAPP.[10]

Electricity tariffs in Burundi have increased since 2012. The average tariff in 2012 was 0.006 US$/kWh, reaching 0.10 US$/kWh in 2013 (see Table 2) and 0.20 US$/kWh in 2017.[25,26] The Government of Burundi and REGIDESO have planned to include additional tariffs in order to balance the costs of fuel, specifically in relation to local thermal power generation. However, both entities must first address the issue of tariff collection, which is currently causing a financial deficit for each kWh sold.[11] Lastly, the demand for electricity is growing at an accelerated pace in Burundi. If the Government manages to increase household access to electricity to 35 per cent by 2030, as predicted by the Burundi's national electricity access programme, electricity demand will increase by at least 10 per cent per year, which will equate to a rise of 192 MW and 933 GWh by 2025.[11]

Table 1. Operational hydropower plants in Burundi

Name	*Location*	*Installed or imported capacity (MW)*	*Operator*	*Commissioning date*
Imports				
Ruzizi I	International-Burundi-DRC	3.5	SNEL	1958
Ruzizi II	International-Burundi-DRC-Rwanda	13.2	SINELAC	1989
Subtotal		**16.7**		
National production				
Rwegura	Kayanza	18	REGIDESO	1986
Mugere	Bujumbura	8	REGIDESO	1982
Nyemanga	Bururi	2.88	REGIDESO	1987
Ruvyironza	Gitega	1.5	REGIDESO	1980
Gikonge	Muramvya	1	REGIDESO	1982
Kayenzi	Muyinga	0.85	REGIDESO	1984
Marangara	Kirundo	0.25	REGIDESO	1986
Buhiga	Karuzi	0.24	REGIDESO	-
6 stand-alone hydropower plants	Various	0.47	ABER	-
12 private hydropower plants	Various	0.65	Private (the Burundi Tea Office and religious missions)	-
Subtotal		**33.84**		
Total		**50.54**		

Source: Ministry of Energy and Mines,[13] Cabinet of Burundi[19]

Table 2. Electricity tariffs in Burundi

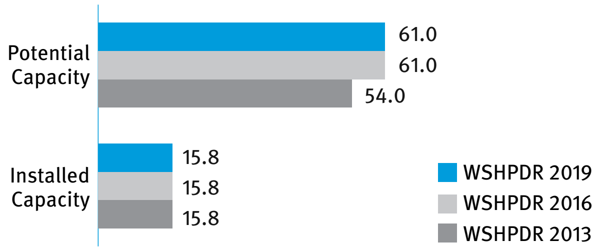
Type of consumption	*Tariff*	*Fixed charge*
	FBU/kWh (US$/kWh)	FBU/Month (US$/kWh)
Households (0-50 kWh)	82 (0.047)	0 (0)
Households (51-150 kWh)	290 (0.166)	0 (0)
Households (≥151 kWh)	546 (0.312)	6,822 (3.898)
Commercial (0-100 kWh)	195 (0.112)	4,122 (2.355)
Commercial (101-250 kWh)	313 (0.179)	8,266 (4.723)
Commercial (≥251 kWh)	399 (0.228)	12,398 (7.085)
Administration	313 (0.179)	11,500 (6.571)

Source: Ministry of Water, Energy and Mines[26]

Small hydropower sector overview

The national definition of small hydropower (SHP) in Burundi classifies SHP plants as those with a generation capacity of up to 1 MW.[12] With regard to the national definition, Burundi has a small or micro-hydropower potential of approximately 30.5 MW and an installed capacity of 3.1 MW.[13] However, with regard to the standard classification of SHP as plants up to 10 MW, the installed capacity in Burundi is 15.84 MW, while the potential, as determined based on planned SHP projects, is 61 MW.[13] Compared to the *World Small Hydropower Development Report (WSHPDR) 2016*, both the installed and potential capacities of SHP have remained unchanged (Figure 3).

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



Source: *WSHPDR 2013*,[15] Ministry of Energy and Mines,[13] *WSHPDR 2016* [25]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*. The data is SHP plants with installed capacity up to 10 MW.

Burundi currently has 12 hydropower plants with capacity less than 1 MW. Six of these 12 are operated by ABER and, of these six, two are non-functional and one requires substantial technical maintenance.[10] The Government of Burundi has reportedly identified 30 sites that are optimal for micro-hydropower development. However, as of now, it does not have the financial capability to develop them.[14] Furthermore, the Government has also had difficulty identifying more viable sites for small or micro-hydropower development, as it currently does not have the funds or human capital to conduct such studies.[14]

The hydropower potential in the country, inclusive of small and large hydropower sites, has been evaluated at approximately 1,700 MW, of which at least 404 MW is economically viable.[10]

Renewable energy policy

The Government of Burundi is implementing policies and regulations to improve the country's renewable energy sector. The goal is to develop the economy, reduce poverty and create more opportunities for income generation from the sector. The strategy for developing the renewable energy sector relies on the following points:

- Improvement of the legislative and institutional framework;
- Sustainable development of rural communities within the framework Sustainable Energy for All;
- Implementation of a law aiming to reorganize the electricity sector of Burundi;
- More transparency on the role of renewable energy in the country's economy;
- Liberalization of the renewable energy sector.[25]

The Government of Burundi has requested assistance from several international organizations, including the United Nations Development Programme, the European Union and the World Bank, in order to carry out feasibility studies. The Government undertook major reforms to improve the business climate in the country and define the process of obtaining construction permits. The ratification of the Protocol on the Establishment of the East African Community (EAC) Common Market compels Burundi to adopt national laws to ensure the strict application of the rules of the treaty.[10] The EAC consists of Burundi, Kenya, the United Republic of Tanzania, Uganda, Rwanda and South Sudan, all of which are in favour of fostering commercial trade among member states.[15]

Burundi has also implemented the following laws that aim to further liberalize the electricity sector:

- Law No. 1/23 of September 24, 2008 defined tax benefits for investors in Burundi;
- Law No. 1/177 of 19 October 2009 established the Investment Promotion Agency, which aims to promote investment and exports and to inform, assist and support investors in obtaining the necessary documents as required by law. The agency will also participate in the discussion of reforms to improve the business climate;
- Law No. 100/318 of December 22, 2011 established the ABER to develop and implement rural electrification projects and programmes, including small-scale hydropower, solar and wind power, as well as other forms of energy that can improve electricity access for the rural population;
- Law No. I/13 of April 23, 2015 aims to reorganize and liberalize the electricity sector;
- Electricity (Generation Services for Export and Electricity Importation) Regulations, 2016;
- Electricity Licensing (Generation Services for Own Use and Trade) Regulations, 2016;
- Electricity (Transmission, Distribution and Electricity Trade) Regulations, 2016;
- Draft of Electricity (Tariff Calculation Procedures), Regulations 2018.[15]

Barriers to small hydropower development

Burundi has made important improvements to the business sector and has made efforts to liberalize the renewable energy sector. However, some major barriers preventing small hydropower development still exist. These include:

- Legal and institutional framework that is unfavourable for investors;
- Lack of funds;
- Lack of local human capital;
- Limited hydrological data.

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1.1.2

Ethiopia

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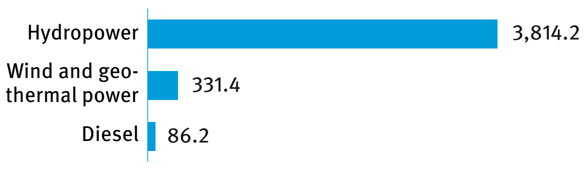
Key facts

Population	99,805,831[1]
Area	1,104,300 km^2
Climate	Ethiopia has a tropical monsoon climate with three distinct climate zones according to elevation: the tropical zone (lowlands) has an average annual temperature of 27 °C. The subtropical (temperate) zone includes some highland areas and has an average temperature of about 22 °C. The cool zone is located above 2,440 metres with an annual average temperature of 16 °C.[1]
Topography	The tropical zone is between 0 and 1,830 metres above sea level, the subtropical zone includes the highland areas between 1,830 and 2,440 metres, and the cool zone is above 2,440 metres in elevation in the western and eastern sections of the high plateaus.[1]
Rain pattern	The tropical zone has annual rainfall of about 510 mm, the subtropical zone between 510 and 1,530 mm and the cool zone between 1,270 and 1,280 mm.[1]
Hydrology	Ethiopia has nine major rivers and 12 big lakes, including Lake Tana, which is the source of the Blue Nile. However, apart from the major rivers and tributaries, there is hardly any perennial flow in areas below 1,500 metres.[9]

Electricity sector overview

Installed capacity in Ethiopia in 2016 was 4,232 MW, of which 90 per cent (3,814 MW) was from hydropower, 8 per cent (331 MW) from wind and geothermal power and the remaining 2 per cent (86 MW) from stand-alone diesel generators (Figure 1).[2,13] The significant increase in the installed capacity from 2013 (2,255 MW) to 2016 was due to the commissioning of the Gilgde Gibe II plant (1,875 MW). The average electricity generation capacity in 2016 was 16,576 GWh/year. The total length of the existing transmission line is approximately 19,323 km.[2]

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

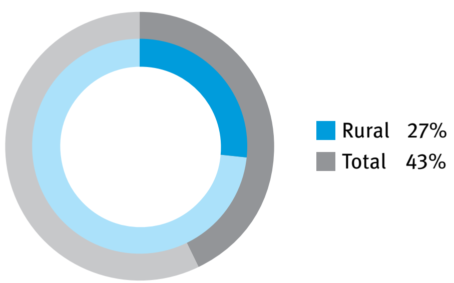


Source: MoST[13]

About 80 per cent of Ethiopians live in rural parts of the nation, and only 27 per cent of rural villagers in 2016 had access to electricity. The electrification rate in urban centres was 85.4 per cent, indicating that total electrification rate was 43 per cent (Figure 2).[10]

The Ethiopian Electric Power (EEP) is the electricity supplier in Ethiopia, whilst the Ethiopian Electric Utility (EEU) is responsible for delivering electricity services and setting the electricity tariffs. The national electricity price is fixed at 0.04 US$/kWh. Since 2002, the Government has subsidized 35 per cent of household consumption. Government policy has been to ensure access to energy to the poor, however, the reality is that most of the poor lack access to electricity. In addition, the fixed low cost of electricity is a disincentive for private domestic and foreign companies to invest in the sector. To solve this problem, the Government of Ethiopia is working on amending national tariffs to attract investors. The new tariff is expected to be implemented in the near future.[7]

Figure 2.
Electrification rate in Ethiopia (%)



Source: WB[10]

Small hydropower sector overview

The definition of small hydropower (SHP) in Ethiopia is up to 10 MW. According to Alphasol Modula Energy PLC, pico- and micro-hydropower plants are classified as power generation systems ranging from 0.1 kW to 100 kW and from 100 kW to 500 kW, respectively. Mini- and small hydropower systems are 500 kW to 10 MW, respectively, and medium and large hydropower plants are above 10 MW.[9]

Installed capacity of SHP is 12.89 MW, while potential capacity is estimated to be 1,500 MW, indicating that less than 1 per cent has been developed.[8,12,13] Since the publication of the *World Small Hydropower Development Report (WSHPDR) 2016*, the installed capacity has doubled, while estimated potential has not changed (Figure 3).

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

Source: *WSHPDR 2013*,[4] GIZ,[8] IRENA, [12] *WSHPDR 2016*,[14] MoST[13]

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

The highland topography, with scattered households and high demand for large cultivated land, as well as the large number of annual flowing small rivers, is well suited for the development of small and micro-hydropower. Due to the seasonal rainfall, the potential for small-scale hydropower is estimated to be 10 per cent of the overall hydropower potential. Most of identified SHP sites are located in the western and south-western parts of the country, with the potential capacity varying according to annual rainfall, which ranges from 300 mm to over 900 mm.

In May 2013, Jimma University, under its community service duty, collaborated with Alphasol Modula Energy PLC and the community to develop a hydropower plant with a generating capacity of 15 kW. In addition, Jimma University, in collaboration with GIZ-ECO, Agricultural Mechanization Research Institute and the Zonal Water and Energy Office, finalized an 18 kW hydropower project in December 2014.

In February 2012, three micro-hydropower plants with a cumulative capacity of 125 kW were inaugurated in the villages of Ererte, Gobecho and Hagara Sodicha in Sidama zone in the Southern Nations, Nationalities and the Peoples' Regional State (SNNPR).

According to a 2010 German Agency for Technical Cooperation Report, small and micro-hydropower are not yet developed on a larger scale in Ethiopia. The three biggest SHP plants were Sor (5 MW), Aba Samual (4.5 MW) and Dembi (0.8 MW), with a national total installed capacity of at least 12.89 MW (Table 1).[8,13]

The market for mini and SHP depends on the ability to feed into the grid. The Ethiopian Energy Authority (EEA) is currently developing a feed-in tariff (FIT) to encourage developers to participate in the development of local resources to generate and sell power. In this regard, a conservative estimate of the market potential for additional capacity is on the order of 1,000 MW, taking into account that only 30 per cent of the technical potential is feasible due to accessibility and grid distance limitations.

Table 1.
List of installed small hydropower plants in Ethiopia

SHP plant name	*River*	*Installed capacity (kW)*	*Potential upgrade up to (kW)*
Sor	Sor	5,000.0	
Aba Samual	Aba Samuale	4,500.0	
Dembi	Gilo	800.0	
Jibo	Jibo	420.0	
Yadot	Yadot	350.0	
Ropi	Bilate	300.0	
Gelenmite	Gelenmite	195.0	
Chemoga	Chemoga	195.0	
Welega	Welega	162.0	
Hulka	Hulka	150.0	
Yaye	Yaye	150.0	170.0
Sotosomere	Sotosomere	147.0	
N/A	N/A	130.0	
Deneba	Deneba	123.0	
Hagara Sodicha	Lalta	43.5	55.0
Rago Senbete		30.0	
Rasa Dango		30.0	
Gobecho II	Gangea	28.0	34.0
Enkule		27.0	
Shebe leku		18.0	
Welega		15.0	
Murago		15.0	
Leku	Boru	13.0	20.0
Kersa		11.8	
Ererte	Ererte	10.0	33.0
Keramo		10.0	
Gera dusta		7.5	
Gobecho I	Gangea	7.0	
Total		**12,887.8**	

Source: Ministry of Water and Energy[13]

In the mid to long term, it is believed that current efforts in developing micro- and pico-hydropower schemes with the support from donors will provide momentum that will encourage developers to see opportunities in mini- and SHP resources. Moreover, the FIT law, which is currently under development, is expected to be implemented in the near future. This will create a market for mini- and SHP plants by providing enhanced opportunities for private companies.[8]

Renewable energy policy

Ethiopia has approximately 48 GW of hydropower potential. In addition, the country has 7 GW of potential from geothermal power, 4-6 kWh/m^2 average solar radiation and 1,350 GW of potential power from wind.

The Government of Ethiopia's energy policy was issued in May 1994 with the objective of ensuring a reliable supply of energy at an affordable price, particularly to support the country's agricultural and industrial development strategies. The key features of the policy are increasing the role of the private sector in electricity generation and establishing a central regulatory authority, the EEA. One of the energy policy's priorities is the enhanced and expanded development and utilization of the country's immense hydropower resources. Energy policy measures in the power subsector include national capacity building in engineering, construction, operation and maintenance and the gradual enhancement of local manufacturing capability of electro-mechanical equipment and appliances.[8,9]

The legal framework for investing in the power sector has been amended and revised. Investment legislation has liberalized the electricity sector by allowing domestic and foreign investors to invest in hydropower of any size. All investment proclamations and regulations concerning power transmission and distribution remain under the auspices of EEU. The establishment of the EEA, which is responsible for issuing operation licence for power generation, recommending tariffs and setting technical standards, was another landmark in the development of the power sector.

However, the absence of a legal framework covering power purchase agreements or FITs has limited power generation by the private sector to only off-grid users. As the grid expands, existing off-grid power generation plants (i.e. SHP and diesel generators) will be abandoned. This has additional consequences in terms of investment risks. The EEA is now drafting a FIT law which is expected to resolve such investment risks and provide opportunities to investors to revive abandoned small and micro-schemes or develop new sites within grid-covered areas.

The FIT law covering renewable energy is drafted and was expected to be implemented by the electricity regulatory agency in 2016. The Rural Electrification Fund (REF) provides concessional loans for the development of off-grid electrification projects. For diesel projects, loans may amount to 85 per cent of the total investment with an interest rate of 7.5 per cent, while renewable energy projects may have a 95 per cent loan with zero interest rate.

Legislation on small hydropower

An environmental impact assessment (EIA) is required for all hydropower plants. However, an exception is made for micro-hydropower, as the requirement for these systems is waived by the regulating authority. If the micro-hydropower project is supported by a loan from the REF, then assessment and approval from all neighbouring upstream and downstream countries is required (as per World Bank regulations). Another requirement for off-grid plants and those connected to mini-grids is a distribution licence, which can be obtained from the regulator. An investment licence is also required (except for cooperatives) and water rights must be approved by the Ministry if the owner is not the community that possesses the water rights.[11]

Barriers to small hydropower development

Key barriers include:

- The absence of rules for decentralized energy production and management;
- Low FIT results in limited incentive for local and foreign investors;
- Poor government support for the development of renewable energy technologies that can be locally manufactured and installed (i.e. the Government should collaborate with higher education institutions on occupational and technical training);
- Lack of local manufacturers and entrepreneurs working in the area of SHP;
- Low level of participation by local and international governmental organizations and non-governmental organizations;
- An increasing population creates increased demand for water consumption.

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1.1.3 Kenya

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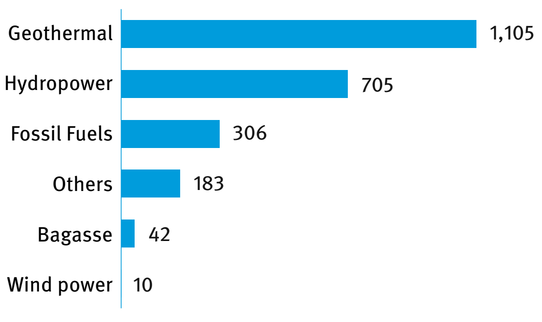
Key facts

Population	50,950,879[1]
Area	580,367 km^2
Climate	Kenya's climate is diverse, ranging from tropical in the southern, western and central regions to arid and semi-arid in the north and northeast.[3] Meanwhile, the country's central highlands have an equatorial climate.[4] The warmest period lasts from February to March, while the coolest is from July to August. Temperatures average between 20 °C and 28 °C. Seasonal variations are distinguished by duration of rainfall rather than by changes of temperature, as seasonal variations in temperature are small.[5]
Topography	Kenya is an African country located on the equator, stretching from latitudes 4° North to 4° South and longitudes 34° to 41°.[2] The geography of Kenya is diverse and varies across its 47 counties.[6] It has a coastline on the Indian Ocean that contains swamps of East African mangroves. Inland are broad plains and numerous hills. Central and Western Kenya is characterized by the Rift Valley, home to Kenya's highest mountain, Mount Kenya, which is the second highest mountain in Africa with an altitude of 5,199 metres above sea level.[5]
Rain pattern	Rainfall in Kenya comes in two seasons: a short one from October to December and a longer one from March to June.[5] Average annual rainfall is 630 mm, with a variation from less than 200 mm in northern Kenya to over 1,800 mm on the slopes of Mount Kenya.[7]
Hydrology	Kenya's drainage system consists of five major basins: Lake Victoria, Rift Valley, Athi and its coastal area, the Tana River and Ewaso-Nyiro North River. The two largest perennial rivers are the Tana River (724 km) and the Athi-Galana-Sabaki River (390 km). Both empty into the Indian Ocean.[8]

Electricity sector overview

Kenya is highly dependent on biomass energy, which provides 70 per cent of the total energy supply. Fossil fuels and electricity provide 21 per cent and 9 per cent, respectively, while other sources provide 1 per cent of the overall energy requirements.[9] Petroleum, which is imported in both crude and refined forms, accounts for 25 per cent of national imports.[10] Access to electricity in Kenya is still low, despite the Government's ambitious target to increase electrical connectivity from the current 15 per cent to at least 65 per cent by the year 2022.[9]

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

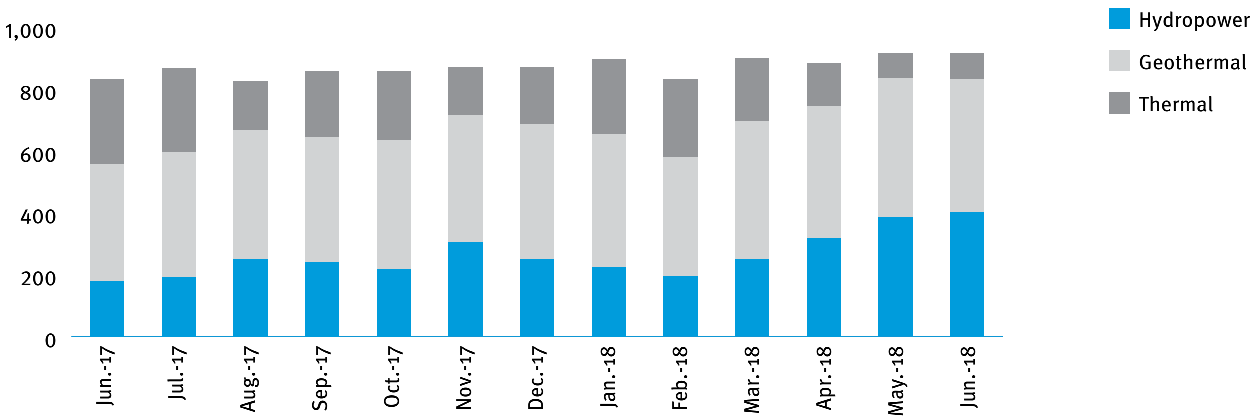


Source: Global Legal Insights[11]

In 2018, installed capacity was 2,351 MW. It comprised of geothermal (47 per cent), hydropower (30 per cent), thermal (13 per cent), bagasse cogeneration (1.8 per cent), wind (0.4 per cent) and others (7.8 per cent) (see Figure 1).[11] In 2018, peak demand was 1,802 MW in June.[12] Demand has increased by 3.6 per cent annually.[12] Current electricity demand is projected to grow from 15,887 GWh to 21,744 GWh by 2020.[13] Besides increasing demand, installed capacity in Kenya has also been rising at a fast pace. Table 1 shows key electricity statistics for the last five years.

Electricity generation increased to 10,205 GWh in 2016/17 from 9,817 GWh in the previous year. This growth is attributed to the positive expansion in commercial/industrial electricity consumption. Geothermal became the largest electricity source at 44 per cent (4,451 GWh) of total electricity generated over the year 2016/17 and is rapidly matching thermal and hydropower sources in terms of the installed capacity (see Figure 2). In 2016/17, hydropower provided 33 per cent (3,341 GWh) of total electricity generated. The contribution from thermal power plants to the total energy mix increased to 21 per cent, up from 13 per cent in 2015/16.[14] However, electricity demand grew by 4.4 percent, from 1,586 MW in 2015/16 to 1,656 MW in 2016/17. Installed and effective capacity stood at 2,333 MW and 2,259 MW, respectively.

Figure 2.
Monthly electricity generation by source (Jun 2017 – Jun 2018) (GWh)



Source: National Bureau of Statistics[17]

Table 1.
Summary of electricity subsector statistics

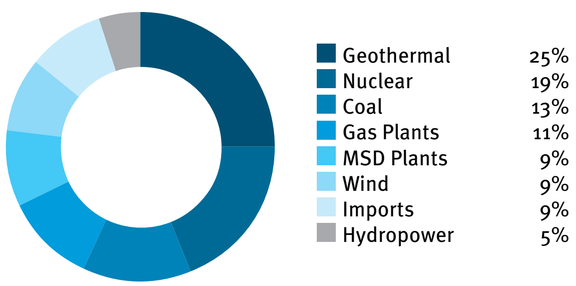
Indicator	*2012/13*	*2013/14*	*2014/15*	*2015/16*	*2016/17*
Installed capacity (MW)	1,800	2,195	2,333	2,341	2,370
Peak demand (MW)	1,354	1,468	1,512	1,586	1,656
Total electricity purchased (GWh)	8,087	8,840	9,280	9,817	10,205
Total electricity sales (GWh)	6,581	7,244	7,655	7,912	8,272
Number of customers connected to electricity	2,330,962	2,767,983	3,611,904	4,890,373	6,182,282

Source: Kenya Power and Lighting Company[14]

Intensive implementation of various connectivity strategies, including the Last Mile Connectivity Project, World Bank's Global Partnership Output-Based Aid Programme and electrification projects targeting informal settlements in urban areas and low-income households in the rural areas, has seen Kenya's power base grow from 2,264,508 customers in March 2013 to 6,526,987 customers as of March 2018. This indicates that total electricity access stood at 73.42 per cent at the end of April 2018, according to Kenya Power.[20] The Government of Kenya is aiming to achieve 100 per cent access to electricity by 2020. According to a World Bank report from 2018, access to electricity among the rural population increased from 7.17 per cent in 2010 to 48.39 per cent in 2018, while access among the urban population improved from 58.2 to 77.6 per cent. However, about 3.2 million households are still without power.[22] This is partly because many live in communities far from the national grid, making it too expensive to connect to the main grid.

Kenya implemented a reformed, decentralized system of governance in 2013, which devolved economic and political power to 47 local, county governments. This devolution created new load centres in counties that now require adequate, secure and reliable electricity supply to support increasing economic activities. Some counties are not covered by the existing transmission and distribution grid. To address these challenges, major reforms have been undertaken, including the liberalization of power generation, unbundling the state power utility company, enactment of the Energy Act of 2006 and the production of a Least Cost Power Development Plan (LCPDP) that incorporates a reserve margin of 25 per cent.[23] Through the updated LCPDP 2013, the Government of Kenya stated its intention to further diversify the supply mix, as shown in the Figure 3. The LCPDP indicated that 26 per cent of the total installed capacity will be obtained from geothermal (25 per cent), nuclear (19 per cent), coal (13 per cent), gas (11 per cent), medium speed diesel (9 per cent), wind (9 per cent), imports (9 per cent) and hydropower (5 per cent).

Figure 3.
Projected generation mix in the year 2030 (%)



Source: Energy Regulatory Commission[23]

The key public sector institutions are:

- Ministry of Energy & Petroleum (MoEP) is the lead government institution responsible for national energy policy formulation, including determining the policy on feed-in tariffs (FIT) and for creating a framework to allow growth, investment and efficient operations in the energy sector. It also grants and revokes generation and distribution licences upon the recommendation of the Energy and Petroleum Regulatory Authority (EPRA);
- Energy Tribunal is an independent legal entity that arbitrates disputes between parties in the energy sector;
- Energy and Petroleum Regulatory Authority (EPRA) is the independent regulator responsible for the economic and technical regulation of electric power, renewable energy as well as downstream and upstream petroleum and coal subsectors, including tariff setting and review, licensing, enforcement, dispute settlement and approval of the power purchase and network service contracts;
- Kenya Power & Lighting Company (KPLC), also known as Kenya Power, is a public company that transmits, distributes and retails electricity to customers in Kenya;
- Kenya Electricity Generating Company (KenGen) owns and operates around 72 per cent of Kenya's installed capacity.[25] KenGen is responsible for developing new public sector generation facilities to meet increased demand;
- Rural Electrification Authority (REA) is a Government-owned entity that came into operation in 2007 and is charged with implementing the Rural Electrification Programme. It came into operation in 2007;
- Geothermal Development Company (GDC) is a Government-owned Special Purpose Vehicle (SPV) that undertakes surface exploration of geothermal fields, appraisals, drilling, steam production and steam sales agreements with investors in geothermal electricity generation;
- Kenya Nuclear Electricity Board (KNEB) is charged with spearheading and fast-tracking the development of nuclear electricity generation to enhance production of affordable and reliable electricity;
- Electricity Transmission Company (KETRACO) is a state-owned company responsible for the development of the national transmission grid network and facilitation of regional power trade through its transmission network;[25]
- Independent power producers (IPPs) are private investors involved in generation, either on large-scale basis or in renewable energy projects under the FIT Policy. IPPs contribute about 28 per cent to the country's installed capacity.[23]

Electricity Transmission Company (KETRACO) implements transmission projects in Kenya. By the end of 2017, transmission lines (200 kV, 132 kV, and 66 kV) covered a distance of 5,978 km. The distribution network consists of 33 kV and 11 kV medium-voltage (MV) lines, which are stepped down to 0.433 kV and 0.24 kV for interconnecting consumers.[14] The entire national electricity distribution network is under KPLC and was 208,934 km long, of which 1,212 km was 66 kV, 30,846 km was 33 kV and 37,234 km was 11 kV.[36] EPRA is in charge of regulating electricity tariffs, but they must be approved by the regulator before enforcement. Consumer tariffs in Kenya as of June 2018 are provided in Table 2.[27]

Table 2.
Consumer tariffs in Kenya as from June 2018

Tariffs	*Monthly fixed cost*	*Energy charges (per kWh)*			*Demand charge (per kVA)*	
			KES	*US$*	*KES*	*US$*
DC (Domestic, 240 V) and IT Domestic water heating	0	above 10 kWh	12.00	0.12	N/A	N/A
		10 kWh or less	15.80	0.16		
SC (Small Commercial, 240 V)	0		15.60	0.16	N/A	N/A
CI1 (Commercial, 415 V)	0	Peak	12.00	0.12	800	8.00
		Off Peak	6.00	0.06		
CI2 (Commercial, 11 kV)	0	Peak	10.90	0.12	520	5.20
		Off Peak	5.45	0.05		
CI3 (Commercial, 33 kV)	0	Peak	10.50	0.11	270	2.70
		Off Peak	5.25	0.05		
CI4 (Commercial, 66 kV)	0	Peak	10.30	0.10	220	2.20
		Off Peak	5.15	0.05		
CI5 (Commercial, 132 kV)	0	Peak	10.10	0.10	220	2.20
		Off Peak	5.05	0.05		

Source: EPRA[28]

Small hydropower sector overview

The local definition of small hydropower (SHP) varies but typically pertains to hydropower projects generating up to 10 MW. The classification of hydropower is expressed in the energy sessional paper number 4 of 2004, summarized in Table 3. The potential for SHP systems is estimated at 3,000 MW.[8] However, only about 39.4 MW have been installed.[26,36,37] Compared to the *World Small Hydropower Development Report (WSHPDR) 2016*, potential capacity has remained the same, while the installed capacity has increased by 22 per cent (see Figure 4). The latest addition was the Gura SHP, with a capacity of 5.8 MW, built in 2017 (Table 4).[37]

Over the past few decades, hydropower has been one of the pillars of the national electricity system in Kenya. However, low rainfall in the country over the years has affected and undermined its hydropower capacity. As a result, there has not been any significant investment in hydropower generation in Kenya recently. Between 2010 and 2016, only 62.21 MW of hydropower capacity (including small and large hydropower) was added to the national grid, increasing capacity from 758.60 MW to 820.81 MW, while current available capacity is 705 MW.[29] After heavy rainfall started in April 2018, the situation has changed. EPRA confirmed that in June 2018, hydropower plants were generating at peak capacity because KenGen's power dams were full following heavy rainfalls in at least 29 counties.[15] KenGen power dams such as Masinga increased water levels from 1,046.7 metres on 24 April 2018 to 1,055.5 metres on 15 May 2018 against a full supply level of 1,056.5 metres above sea level. Similarly, Kiambere, Kamburu, Gitaru and Kindaruma also registered high levels.[30] This was the first time the dams recorded high water inflows since 2015. This is an indication that hydropower production will possibly increase further in 2018, and there are possibilities of constructing SHP stations to provide affordable electricity to local communities.

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

Source: *WSHPDR 2013,*[32] *WSHPDR 2016,*[25] Gichimu J.M and Mercy M.,[26] LCPDP,[36] KTDA[37]

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

Table 3.
Small hydropower definition in Kenya

Category	*Power range*
Pico	< 5 kW
Micro	from 5 kW to 100 kW
Mini	from 100 kW to 1,000 kW
Small	from 1,000 kW to 3,000 kW

Source: Ministry of Energy[29]

Existing SHP plants have varying ownership structures, including private, community or public ownership models. Most of the commercial and public plants are operational and, generally, in good condition, while most of the community plants are in need of significant refurbishment. A summary of existing SHP plants is provided in Table 4. Several entities, such as tea factories, have started initiatives to develop SHP projects in their catchment areas.

There are several micro-hydropower schemes under private ownership, particularly in the tea estates, whose exact capacities have not yet been officially determined. The highlands in the wetter part of the country, such as in Mount Kenya, Aberdare, Nyambene and Mount Elgon, hold the largest hydropower potential. Other areas with considerable potential are the Kisii highlands, Nandi hills, Cherangani hills, Kerio and Mau escarpment, and, to a lesser extent, the Shimba hills by the coast. The project ''Greening the Tea Industry in East Africa (GTIEA)'' is an initiative being implemented by the East African Tea Trade Association (EATTA) and complemented by United Nations Environment Programme (UNEP) and the African Development Bank (AfDB). It is developing SHP sites in tea growing areas of East, Central and Southern Africa, in order to reduce tea factories' overdependence on the national grid.

Table 4.
The capacity of small hydropower installed in different rivers between 1925 and 2009 in Kenya (MW)

Plant	*Year constructed*	*Ownership*	*River*	*Installed capacity (MW)*
Ndula	1925	KenGen	Thika	2.0
Mesco	1933	KenGen	Maragua	0.38
Selby falls	1952	KenGen	N/A	0.4
Sagana Falls	1955	KenGen	Tana	1.5
Gogo Falls	1958	Mining Co.	Migori	2.0
Tana 1 & 2	1952	KenGen	Tana	4.0
Tana 3	1952	KenGen	Tana	2.4
Tana 4	1954	KenGen	Tana	4.0
Tana 5	1955	KenGen	Tana	4.0
Wanjii 1 & 2	1952	KenGen	Maragua	5.4
Wanjii 3 & 4	1952	KenGen	Maragua	2.0
Sosiani	1955	KenGen	Sosiani	0.4
James Finlay 1	1934	Tea Company (James Finlay)	Kericho	0.3
James Finlay 2	1934	Tea Company (James Finlay)	Kericho	0.4
James Finlay 3	1980	Tea Company (James Finlay)	Kericho	0.1
James Finlay 4	1984	Tea Company (James Finlay)	Kericho	0.3
James Finlay 5	1999	Tea Company (James Finlay)	Kericho	1.1
Brooke Bond 1	-	Tea Company (Brooke Bond)	N/A	0.09
Brooke Bond 2	-	Tea Company (Brooke Bond)	N/A	0.1
Brooke Bond 3	-	Tea Company (Brooke Bond)	N/A	0.18
Brooke Bond 4	-	Tea Company (Brooke Bond)	N/A	0.24
Savani	1927	Eastern Produce	N/A	0.09
Diguna	1997	Missionary	N/A	0.4
Tenwek	-	Missionary	N/A	0.32
Mujwa	-	Missionary	N/A	0.01
Community MHPs	2002	-	N/A	0.02
Tungu kabiru	2000	Community	Tungu	0.01
Thima	2001	Community	Mukengeria	0.01
Kathamba	2001	Community	Kathamba	0.001
Imenti	2009	KTDA	Imenti	0.9
Gikira	2016	Community	Gikira	0.514
Gura	2017	KTDA	Gura	5.8
Total				**39.37**

Source: Gichimu J.M and Mercy M.,[26] Harrison, M.,[25] LCPDP,[36] KTDA[37]

A number of potential sites across the country are currently at advanced stages of pre-development, with the notable presence of private investors such as Virunga Power, ResponsAbility Africa, Frontier, VS Hydro and Gulf Energy. Potential sites marked for development by the private sector in the medium-term include Broderick Falls, Mutunguru, Mathioya Cascade and Yala Falls. According to ERC, a total of 44 proposals for developing SHP projects under the FIT scheme with a total capacity of 194 MW had been approved as of June 2014, with many more projects still under consideration.

Renewable energy policy

The FIT scheme was introduced in 2008 and revised in 2010 and 2012. The updated version of the policy contained revised tariffs for biomass and wind generation, as well as the introduction of tariffs for biogas, solar and geothermal resources. This policy is intended to attract private investment in renewable energy electricity generation. FITs allow power producers to sell, and obligate the distributor to buy, all electricity generated by renewable energy sources on a priority basis and at a pre-determined fixed tariff for a defined period of 20 years. Table 5 shows the applicable grid-connected power tariffs.

Table 5.
Feed-in tariffs (2012) for renewable energy projects in Kenya

Plant type	*Installed capacity (MW)*	*Standard FIT (US$/ kWh)*	*Scalable portion of the tariff*	*Minimum capacity (MW)*	*Maximum capacity (MW)*
Wind	0.5 – 10	0.1100	12 %	0.5	10
Hydro-power	0.5 10	0.1050 0.0825	8 %	0.5	10
Biomass	0.5 - 10	0.1000	15 %	0.5	10
Biogas	0.2 - 10	0.1000	15 %	0.2	10
Solar (grid)	0.5 - 10	0.1200	8 %	0.5	10
Solar (off-grid)	0.5 - 10	0.2000	8 %	0.5	10

Source: Draft National Energy and Petroleum Policy 2015 [32]

Note: For values between 0.5 MW and 10 MW, interpolation shall be applied to determine tariff for hydropower

Sessional Paper No. 4 of 2004 is the policy document that cements the liberalization reforms in the energy sector that took place in the mid-1990s. The paper set out the policy framework applied in national energy strategies and in the Energy Act of 2006. The Energy Act 2006 provides the legal and regulatory structure for the power sector in the country and defines the Government's role as being in coordination, management and policy formulation. The Energy (Electricity Licensing) Regulations of 2012 details the regulations, including permit and licence requirements, that are applied to any individual or entity undertaking or planning to engage in electricity generation, transmission, distribution or retail in Kenya.

Besides the main frameworks, Kenya's renewable energy development is also considered and stimulated through various strategies and plans, including:

- Kenya Vision 2030, in which energy is defined as a key foundation and one of the infrastructural "enablers" upon which the pillars of Kenya's long-term development strategy will be built. The successful implementation of Kenya Vision 2030 flagship projects will greatly depend on the supply of adequate, reliable, clean and affordable energy. Electricity generation must increase, since it is a prime mover of the economy's commercial sector;
- The National Climate Change Response Strategy of 2010 was established as a measure of mitigation and adaptation to climate change. Apart from the focus on pursuing an energy mix that emphasizes carbon–neutral energy sources, it also reviews the country's building codes to incorporate measures that will encourage climate–proofing and the construction of energy efficient buildings;
- The Rural Electrification Master plan is an evolving plan covering electrification of rural areas through the rural electrification program, which is updated on an annual basis in order to respond to the most urgent needs of rural populations regarding electricity connectivity. The plan states the Government's goal of achieving 100 per cent connectivity across the country through grid expansion and off-grid systems;
- The LCPDP is a Kenya Energy Sector Report intended to guide the country on the sector status, generation expansion opportunities, transmission infrastructure target network expansion and resource requirements for the country's expansion programme;
- The Investment Plan for Scaling-Up Renewable Energy (SREP) supports the implementation of hybrid mini-grid systems with renewable energy sources for electrification in rural areas where grid extension is unlikely to be viable in the short- and medium-term

Barriers to small hydropower development

SHP is impeded by the following:

- High investment costs to develop, construct and operate SHP schemes;
- Poor quality of hydrological, climate and statistical data, especially in remote areas, far from central cities, where there are suitable locations for SHP projects;
- Lack of infrastructure for the production, installation and maintenance of SHP systems;
- Lack of development and refinement in government policies and efforts targeting local communities' participation in SHP project development;
- Financing constraints for renewable energy projects have contributed to the limited investment flows from the private sector to SHP projects;
- Long procedures and regulatory inconsistency in approving power purchase agreements.

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Madagascar

1.1.4

Tsiky Harivelo Robison, Ministry of Water, Energy and Hydrocarbons

Keys facts

Population	24,894,551[1]
Area	587,041 km[2]
Climate	Madagascar's climate is humid tropical along the east coast with the coolest month's temperature being 15 °C on average, temperate inland and in the north and arid in the south, with the coolest month's temperature being 20 °C on average. There are two seasons in Madagascar: the dry and cool season from May to October; and the rainy and hot season from November to mid-April, which is also the cyclonic season. The geographical situation, the shape of the relief, the maritime influence and the wind regime are the primary causes of the very varied climatic conditions on the island.[2]
Topography	A mountainous backbone culminating between 800 and 1,500 meters of altitude traverses the along the island's entire length from north to south. The relief divides the country into three bands: a narrow coastal strip in the east, high plateaus in the centre and an area of lower plateaus and plains in the west. The Tsaratanana Massif has the highest peak on the island (Mount Maromokotro at 2,876 metres).[3]
Rain pattern	Madagascar is located almost entirely in the tropical zone. The east coast, directly exposed to the trade winds, has a humid tropical climate and receives upwards of 1,500 mm of rainfall annually. The centre is drier and receives an annual rainfall of 1,400 mm. The west coast has a dry tropical climate and receives less than 800 mm of rainfall annually. The southwestern part has a semi-arid climate: rainfall is less than 400 mm annually, with more than eight dry months.[3]
Hydrology	As the fourth largest island in the world, Madagascar has more than 10 major rivers whose tributaries form river networks covering nearly the entire country. The asymmetrical character of the island's relief has a direct consequence on the drainage pattern: the longest rivers are those in the west, while shorter rivers in the east have a more accentuated profile, with many falls that are sometimes very important. The physical characteristics and the passages of the depressions and tropical cyclones lead to extreme complex hydrological regimes.[3]

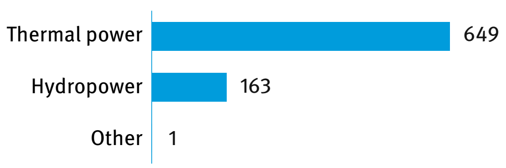
Electricity sector overview

The Ministry of Water, Energy and Hydrocarbons (MWEH) is responsible for the design and implementation of the country's energy policy in order to ensure energy supply meets the demand with better quality and at a lower cost.[4] Madagascar has significant renewable energy resources (hydropower, solar, wind and biomass), but overall energy consumption is still very low. Energy consumption is still dominated by wood and its derivatives.

Madagascar has three interconnected grids – Antananarivo (RIA), Toamasina (RIT) and Fianarantsoa (RIF) – and several mini-grids and autonomous centres. The national electricity utility JIRAMA is the country's largest electricity supplier. In 2017, the installed capacity operated by JIRAMA was 804 MW, with an available capacity of 506 MW.[5] For rural communities, the installed capacity was 7,865 kW.[6] The country's total installed capacity was 812 MW, with approximately 163 MW of hydropower.[5]

The energy mix is shared between hydroelectric plants that supply 54 per cent of the country's energy and thermal power stations that supply the rest (46 per cent). Solar, wind and biomass are still negligible sources of energy. In 2016, JIRAMA's electricity production was 1,651 GWh.[5]

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



Source: MWEH,[4] ADER,[6] JIRAMA [5]

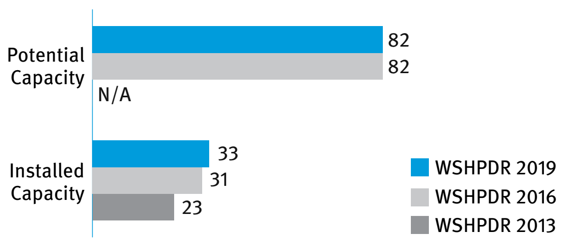
In 2016, the national electrification rate was 15 per cent, while the electrification rate in rural areas was 6.1 per cent.[4] To raise this rate, Madagascar has defined a new energy policy with the goal to achieve a 70 per cent national electrification rate by 2030.[7]

The institutional organization of the electricity sector in Madagascar is composed of a ministry (MWEH), a regulator, a rural electrification agency, a national public operator (JIRAMA) and private operators. The MWEH is the authority responsible for the design and implementation of energy policy to ensure a satisfactory supply of better quality at a lower cost. The energy sector is currently governed by Law 98-032. The new law known as the Electricity Code, which is part of the implementation of energy policy, will be applied from year 2018. The Rural Electrification Development Agency (ADER) is largely responsible for rural electrification. Its mission is to implement the rural electricity subsector policy. ADER works with different donors and investors to achieve the objectives.

The Electricity Regulatory Agency, (ORE) (now the Electricity Regulation Authority [ARELEC] following recent legislation) is the regulator of the electricity sector in charge of determining, publishing and monitoring electricity prices. ORE issues and regulates electricity tariffs. However tariffs between producers and carriers for interconnected grids and between producers and distributors for autonomous grids are not regulated. Instead these prices are fixed according to mutual agreement between the two parties in a "Purchase Agreement", with tariffs differing according to the source of production. For JIRAMA, the tariff varies according to zones.[8] Currently, there is an ongoing project coordinated by ORE to develop the grid code to ensure the smooth operation of technical operations related to the grids managed by JIRAMA.

Small hydropower sector overview

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



Source: MWEH,[4] ORE,[8] ADER,[6] JIRAMA,[5] *WSHPDR 2013*,[10] *WSHPDR 2016*[9]

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

The installed hydroelectric capacity of Madagascar is 163 MW, while the total theoretical potential is estimated at 7,800 MW. Madagascar has no official definition of small hydropower (SHP). In 2017, the combined capacity of SHPs up to 10 MW was about 33 MW (Figure 2; Table 1). In comparison to the *World Small Hydropower Development Report (WSHPDR) 2016*, the installed capacity has increased by 6.5 per cent.

According to the Renewable Energy Resource Mapping: Small Hydro Madagascar, funded by ESMAP and implemented by the World Bank, without technical or economic considerations, the SHP potential in Madagascar consists of more than 350 potential sites ranging from 1 to 20 MW, with a cumulative capacity of approximately 1,350 MW.

Regarding the licences to develop electricity, there are the "authorization", "concession", and "declaration". New thresholds are set to encourage developers to invest in renewable energy to simplify and facilitate administrative arrangements for producers. For hydropower, the power thresholds are described in the Table 2.[4]

Table 1.
Small hydropower installed capacity in Madagascar

Site location	*Grid*	*Installed capacity (MW)*	*Operator*	*Date*	*Generation (GWh/yr)*
Antelomita 1 & 2	RIA	8.80	JIRAMA	1952	30.29
Tsiazompaniry	RIA	5.20	Henri FRAISE Fils & Cie	2010	15.70
Manandona	RIA	1.60	JIRAMA	1930	-
Volobe	RIT	6.80	JIRAMA	1931	40.45
Namorona	RIF	5.60	JIRAMA	1980	32.99
Manandray	RIF	0.45	JIRAMA	1932	-
Maroantsetra	JIRAMA Maroantsetra	2.60	HYDELEC	2010	4.13
Ihosy	Sahambano	0.70	ERMA	2015	-
Fandriana	Fandriana	0.56	HIER	2014	-
Ambodiriana[a]	Vatomandry	130	JIRAMA	1953	-
Ankazomiriotra[a,b]	Ankazomiriotra	120	POWER & WATER	2009	-
Ankilizato	Ankilizato	0.10	HIER	2015	-
Andriba	Andriba	0.08	SERMAD	2014	-
Tolongoina	Tolongoina	0.06	SM3E	2013	-
Soavina Ilaka centre	Soavina Ilaka centre	0.06	HIER	2015	-
Amboasary Anjozorobe	Amboasary Nord	0.08	AIDER	2017	-
Total		**32.94**			

Source: MWEH,[4] ORE,[8] ADER,[6] JIRAMA,[5] *WSHPDR 2016* [9]

Note: (a) need for refurbishment, (b) destroyed during the cyclone in January 2018.
Note: Hydropower stations below 50 kW are not included in this table.

Table 2.
Power threshold for hydropower

Type	Installed capacity	
	Current Law (No. 98-032)	*Code of electricity (in coming law)*
Declaration	-	≤500 kW
Authorization	≤150 kW	500 kW <P ≤ 5 MW
Concession	>150 kW	> 5 MW

Source: MWEH[4]

Note: This table is for hydropower infrastructure only, energy transmission and distribution are governed by other thresholds

There were several planned and ongoing renewable energy projects to replace the existing thermal power plants (Table 3).

Table 3.
Planned small hydropower in Madagascar

Site location	*Grid*	*MW*	*Operator*
Amboasary*	RIA	2.00	MADO SAINTO
Androkabe*	Ambatondrazaka Amparafaravola	1.60	BETC
Maheriara*	Ambatondrazaka Amparafaravola	0.70	BETC
Sahatona	Sahatona	0.30	HIER
Belaoko Lokoho	Andapa, Sambava	8.00	HIER
Andriamanjavona	Vohémar	0.70	MADEN
Marobakoly	Antsohihy	0.25	SRAFI
Mandalobe	Tsiroanomandidy	0.25	CASIELEC
Angodongodo	Ihosy	0.15	HFF
Ampitabepoaky	Tsiroanomandidy	1.10	HFF
Total		**15.05**	

Source: MWEH,[4] ADER[6]

Note: *under construction

Madagascar has great potential for small hydropower sites. The Government is seeking the contribution of the national and international private sectors, as well as technical and financial partners, to finance a significant portion of the investments planned for the development of the sector.

Renewable energy policy

Madagascar's New Energy Policy (NEP) for 2015-2030 was defined in 2015. The vision of the NEP is based on a basic principle of least cost and five qualitative objectives for the sector: access for all to modern energy, affordability, quality and reliability of services, energy security and sustainability. The vision, in terms of electrification and access to the lighting, is to reach 70 per cent of households by 2030, in comparison to 15 per cent in 2018. This implies a generation of 7,900 GWh of electricity in 2030 (including individual production), with 2,500 MW of additional installed capacity compared to 2015.

This goal will be achieved with 70 per cent interconnected grids (with a 75 per cent hydroelectric generation mix, 15 per cent thermal, 5 per cent wind and 5 per cent solar); 20 per cent mini-grids (with a 50 per cent hydropower production mix, 20 per cent biogas, 25 per cent diesel and 5 per cent solar); 5 per cent domestic solar system; and 5 per cent solar lamps.[7]

In total, 80 per cent of the energy mix targeted for 2030 will be of renewable origin, and about 60 per cent of households, businesses and industries will adopt efficient electricity consumption measures.

The new Electricity Code promotes the development of renewable energies especially hydroelectric. The Electricity Code will simplify procedures for the implementation of renewable energy installations and increase the power threshold for the different authorizations.

Barriers to small hydropower development

Madagascar has considerable potential in SHP to achieve the goals set forth in its energy policy. The implementation of the new sector law in 2018 should solve some problems related to the development of small hydropower.

There are several key challenges:
- Lack of hydrological data for site development;
- Lack of the legal, regulatory and institutional frameworks to apply tariffs and improve the financial attractiveness and technical performance of the electricity sector;
- Lack of a well-structured renewable energy development plan and evaluation monitoring system;
- Insufficient financial resources to cope with the high investment costs of renewable energy technologies;
- Limited technical capacity and human capital in the energy sector and, more specifically, in the renewable energy subsector;
- Lack of private sector mobilization.[4]

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1.1.5

Malawi

Gift Chiwayula, Department of Energy Affairs

Key facts

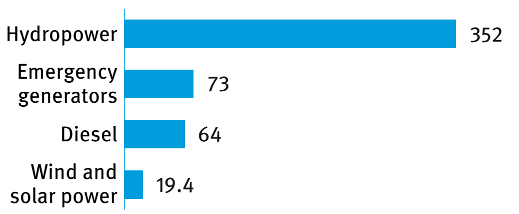
Population	19,196,246[1]
Area	118,484 km^2 [1]
Climate	The climate of Malawi is typically sub-tropical: the rainy season is from November to May, while dry season is from May to November. Variations in altitude in Malawi lead to wide differences in climate. Mean annual temperature is 24 °C. November is the hottest month, with temperatures reaching an average daily maximum of 29 °C. July is the coolest, with temperatures dropping to an average daily maximum of 23 °C.[6]
Topography	Malawi lies within the Great Rift Valley system. Lake Malawi, a body of water 580 km long and 460 metres above sea level, is the country's most prominent physical feature. Approximately 75 per cent of the land surface are plateaus between 750 and 1,350 metres above sea level. Highland elevations rise to over 2,440 metres in the Nyika Plateau in the north and to 3,000 metres at Mount Sapitwa, the country's highest point. The lowest point is on the southern border, where the Shire River meets the Zambezi River at 37 metres above sea level.[16]
Rain pattern	Precipitation is heaviest along the northern coast of Lake Malawi, where the average annual rainfall is more than 1,630 mm. Approximately 70 per cent of the country averages between 750 mm and 1,000 mm of precipitation annually.[16]
Hydrology	Malawi's main water source is Lake Malawi, which stretches along the eastern borders with the United Republic of Tanzania and Mozambique and accounts for approximately 20 per cent of the country's total area. The most significant river is the Shire River (402 km long) which is Lake Malawi's only outlet, flowing south into Mozambique, where it meets the Zambezi River.[16]

Electricity sector overview

In 2016/17, the total installed capacity was 508.4 MW. Installed hydropower capacity was 352 MW, 64 MW were diesel power, 73 MW were additional emergency generators and 19.4 MW were wind and solar power plants (see Figure 1).[7] Annual generation was 1,854.82 GWh, which has since decreased due to lower water levels. Approximately 80 per cent of the country's installed capacity is from the state-owned Electricity Supply Corporation of Malawi (ESCOM) which operates the majority of the plants in the country, primarily from various hydropower plants and three diesel plants.[5] According to ESCOM, however, over 50 per cent of plants have surpassed their life expectancy and require regular maintenance in order to improve their efficiency.[14] The remaining 20 per cent (about 70 MW) of capacity is privately owned.

Currently, 95 per cent of the capacity that fuels the grid is sourced from just one river, the Shire. Peak demand currently exceeds the supply by almost 100 MW, and the gap is expected to grow significantly by 2030, when the expected demand should be 1,873 MW.[2,3] Malawi has a remarkably low electrification rate at around 12 per cent, leaving the majority of the rural population dependent on biomass as the main energy source. While access to electricity has increased, reaching almost 46 per cent of urban households, rural electrification is still only 5 per cent in a country where the majority of the population (more than 84.5 per cent) lives in rural areas (Figure 2).[5] By 2030, Malawi aims to have a 30 per cent national access rate.[3,4]

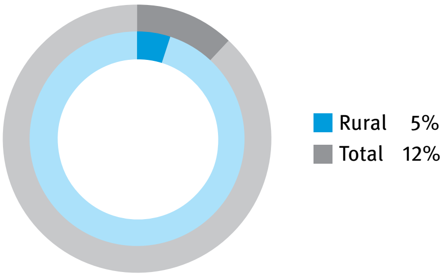
Figure 1.
Installed electricity capacity by sector in Malawi (MW)



Source: ESCOM[7]

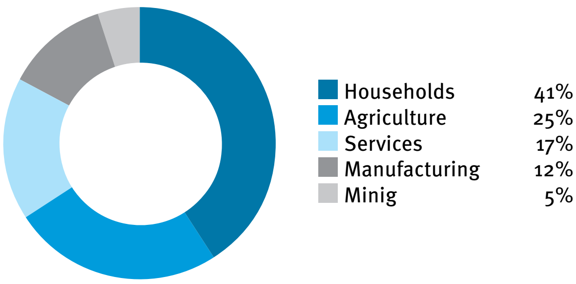
Distribution of the electricity demand is as follows: 41 per cent households, 25 per cent agriculture, 17 per cent services, 12 per cent manufacturing and 5 per cent mining (Figure 3).[3] The Government plans to increase annual generation from the current 1,854.82 GWh to 2,364 GWh by 2020 and 3,300 GWh by 2025.[23] As grid extension is difficult, the Government is considering off-grid options, such as small and micro-hydropower plants, solar and wind. Most of the country's energy needs are met by the use of biomass, such as fuel wood and charcoal, although Malawi is endowed with considerable access to alternative energy resources, such as solar, wind, hydropower and geothermal.[13]

Figure 2.
Electrification rate in Malawi (%)



Source: Energy Demand and Supply for Malawi[3]

Figure 3.
Electricity use by sector in Malawi (%)



Source: Energy Demand and Supply for Malawi[3]

The Government of Malawi is making efforts to increase the capacity of generated electricity by expanding the existing power plants and constructing new power plants. Feasibility studies are currently underway for various energy sources that can be integrated into the energy mix, including hydropower sites, coal sites, bagasse resources and geothermal, wind and solar mapping. Plans are also underway to connect to the Zambian and Tanzanian power grids, providing investors with access to the regional power markets.[2]

ESCOM, which was previously the sole provider of the grid electricity in Malawi, has been unbundled into two companies, with Electricity Generation Company (EGENCO) now responsible for generation while ESCOM retains responsibility for transmission and distribution.

The electricity tariffs differ depending on the type of customer and the phase supply being used (see Table 1) and are lower than the tariffs in the Southern African Development Community (SADC) region and other neighbouring countries. The tariffs are regulated by the Malawi Energy Regulatory Authority (MERA), which is also the main regulator of all other fuels.[14]

In general, the electricity sector faces a lot of challenges, including a lack of independent power producers and a lack of financial resources and clear policy guidelines to promote private investment. Another challenge is the weather pattern, which is affecting the generation capacity and has resulted in procurement of diesel generators (73 MW) in order to meet demand. In 2014, the Millennium Challenge Corporation provided a US$ 250.7 million contract with the Government of Malawi in order to help overcome some of these challenges.[19]

Table 1.
Electricity tariffs in Malawi

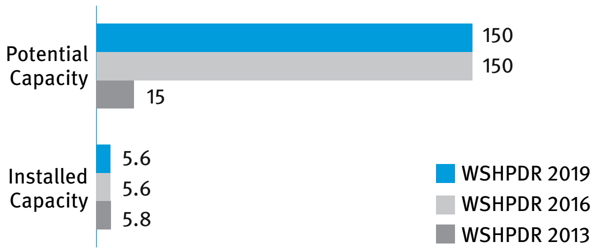
Type of customer	*Description*	*Tariff (US$/kWh per month)*
Domestic	Single phase supply Three phase supply	0.062 0.10
Commercial	Single Phase supply Three Phase	0.11 0.12
Industrial	On peak Off peak	0.11 0.03

Source: ESCOM (2018)[13]

Small hydropower sector overview

In Malawi, small hydropower (SHP) is defined as plants with an installed capacity less than 5 MW. Total installed capacity for SHP plants under 5 MW is approximately 5.6 MW, with an additional proven potential of at least 7.7 MW and a theoretical estimated potential of 150 MW.[16,17] This indicates that approximately 4 per cent of the country's known potential has been developed so far. Compared to data from the *World Small Hydropower Development Report (WSHPDR) 2016*, the installed capacity has remained unchanged.

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



Source: *WSHPDR 2016*,[14] *WSHPDR 2013*,[15] MEM,[16] Taulo et al.[5]

Note: For plants less than 5 MW. The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

Currently there is one working SHP plant connected to the power utility grid with an installed capacity of 4.5 MW being run by ESCOM. There are other off-grid SHP plants that are also currently working: the Lujeri mini-hydropower plant with a capacity of 1 MW, the Mulanje Electricity Generating Agency (MEGA) with a capacity of 88 kW and the Kavuzi mini-hydropower plant with a capacity of 10 kW (see Table 1). MEGA is part of a programme run by Practical Action and is currently undergoing feasibility studies in advance of an upgrade to 2 MW.[1] There are also some SHP plants that are not functioning, including one in Matandani, Neno, however, it is still being maintained by the Malawi Industrial Research and Development Centre. Scottish funding was secured in 2015 for a 100 kW run-of-river scheme near Mulanje.[2]

Currently just 1.6 per cent of the total installed hydropower capacity of 351 MW is from SHP plants.

Malawi has an SHP potential of approximately 7.7 MW, while a 1997 study by the Ministry of Energy and Mines (presently the Ministry of Natural Resources, Energy and Environment) estimated the theoretical potential to be 150 MW.[10,16] Practical Action's MEGA project is looking to develop a number of micro-power plants up to 500 kW capacity, suggesting that the country's full micro-hydropower potential could generate 15.6 GWh per annum.[9] Table 2 shows the pico-hydropower potential of 11 selected sites that have been studied in Malawi. Financing mechanisms are limited to either bank loans or small grants from donors such as the Global Environment Facility (GEF). GEF, through the Department of Energy Affairs, is implementing a project to promote mini-grids, and one component of the project is to upscale MEGA by adding 100 kW. Another grant has been awarded to Practical Action to develop an SHP plant in Nkhata Bay at Usingini of 300 kW.[14]

Table 2.
Potential pico-hydropower sites in Malawi (partial list)

District	*Site*	*Distance from grid (km)*	*River*	*Estimated flow (m/s)*	*Estimated Capacity (kW)*
Chitipa	Chisenga	35	Chisenga	0.1	15
Chitipa	Mulembe	35	Kakasu	0.1	15
Chitipa	Nthalire	102	Choyoti	0.2	60
Rumphi	Katowo	45	Hewe	0.2	45
Rumphi	Nchenachena	23	Nchenachena	0.2	30
Nkhatabay	Khondowe	-	Murwezi	0.05	5
Nkhatabay	Ruarwe	-	Lizunkhuni	0.15	50
Nkhatabay	Usisya	50	Sasasa	0.1	20
Mangochi	Kwisimba	38	Ngapani	0.05	5
Mangochi	Katema	23	Mtemankhokwe	0.1	25
Thyolo	Sandama	6	Nswazi	1	75
Total					345

Source: *WSHPDR 2016* [14]

Renewable energy policies

The Department of Energy Affairs in Malawi has reviewed the previous NEP which was outdated. The updated NEP states that there should be a Renewable Energy Strategy for Malawi, which has already been developed and approved with the aim of promoting renewable energy technologies in Malawi, including SHP.[21] The Renewable Energy Strategy for Malawi has the following objectives:

- Implement incentives on renewable energy technologies, such as tax waivers, to minimize costs;
- Capacity building in renewable energy technologies;
- Awareness campaigns;
- Set up a Grouping for Renewable Energy Stakeholders to oversee the implementation of renewable energy projects in Malawi;
- Development of feed-in tariffs and a power purchase agreements framework.

Facing new challenges due to climate change and subsequent water shortages, the NEP will further diversify the energy mix with a major focus on renewable sources, such as solar and wind. The NEP is expected to raise the renewable energy target to 11 per cent by 2020 and 22 per cent by 2030, with the aim to establish Malawi as a carbon neutral country by 2035.[10,11]

Barriers to small hydropower development

These are the main barriers to SHP development currently present in Malawi:

- Investments needed: a key challenge is the lack of investors to develop SHP due to limited finance capacity. The Government is hoping to overcome these challenges by developing a conducive environment for private investors and conducting feasibility studies for independent power producers;
- Deforestation: the use of biomass and natural woodland as sources of energy has led to deforestation, which degrades catchment areas, leading to siltation and reduced base flows in rivers;
- Aging infrastructure: installed infrastructure has been impacted by extreme weather events, such as droughts and floods. The system experiences termite attacks, the natural rotting of wood structures, bush fires burning of wooden poles and even vandalism of both wood and steel tower structures;
- Energy access: the Malawi Rural Electrification Programme (MAREP) effort could have easily yielded 20 to 25 per cent access to grid electricity if the rural population was also economically empowered to afford paying for the upfront costs of wiring, inspection and connection. This calls for an innovative model for rural energy access beyond the grid extension;
- Operational concerns: floating aquatic weeds and debris being transported in the Shire River have caused severe operational problems and damage to intake structures at generation plants. Siltation of power plants reservoirs has also contributed immensely to the operational problems. Theft and vandalism of ESCOM infrastructures, illegal connections to the grid, encroachment of ESCOM wayleave and illegal extensions of electricity have contributed to huge financial losses;
- Lack of information and awareness among the population;
- Human capital: there is a need for skilled workers at all levels of renewable energy sector, including products, services, installations and maintenance.[5,14,22]

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1.1.6

Mauritius

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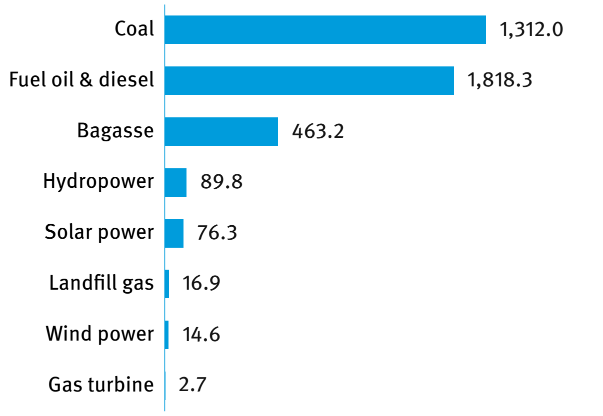
Key facts

Population	1,263,820[1]
Area	1,865 km[2]
Climate	Mauritius has a mild, tropical, maritime climate with little variation between the two seasons, summer and winter. Summer is warm and humid, lasting from November to April, with an average temperature of 24.7 °C. Winter is comparatively cooler and drier, with an average temperature of 20.4 °C.[2,15]
Topography	The island is mostly a volcanic formation surrounded by coral reefs. A coastal plain is followed by a central plateau between 275 and 580 meters high, with surrounding mountain chains and some isolated peaks. The highest point, Piton de la Petite Riviere Noire, is 828 meters above sea level.[3,15]
Rain pattern	Annual precipitation has a total volume of approximately 3,821 million m³. Average annual rainfall is 2,010 mm. Although there is no marked rainy season, most of the rainfall occurs in the summer months. Average summer rainfall is 1,344 mm, accounting for 67 per cent of the country's total rainfall. Average winter rainfall is 666 mm.[4,15]
Hydrology	There are 20 main rivers in Mauritius. The longest is the Grand River South East (Grande Rivière Sud-Est) which is roughly 27.67 km long and is located in the central-eastern region. The other main rivers include the Black River (Rivière Noire), Post River (Rivière du Poste), Grand River North West and Rempart River. Several waterfalls exist, with the highest being the Tamarin Falls in the west at 293 meters.[3] There are also 10 man-made reservoirs on the island.[5,15]

Electricity sector overview

In 2017, the total installed capacity in Mauritius was 825.5 MW with a total available capacity of 767.3 MW. The peak power demand in 2017 reached 461.5 MW with electricity generation reaching 3,156.8 GWh in the same year. Sources of electricity in Mauritius include coal, diesel and fuel oil, kerosene, hydropower, bagasse, solar, wind and landfill gas. Coal and diesel together contribute almost 80 per cent of the country's electricity generation. This is followed by bagasse, which accounts for roughly 15 per cent. Figure 1 offers more information on electricity generation by source.[4]

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



Source: Mauritius Government Statistics[4]

Renewable resources generated 661 GWh in 2017 and represented 21 per cent of the total electricity production. Bagasse accounted for over 75 per cent of generation. The remaining sources accounted for just 6.3 per cent of the total electricity production. Of this 6.3 per cent, hydropower accounted for 2.9 per cent.[4]

The electrification rate is high at 99.4 per cent, with 100 per cent of the urban population receiving electricity and more than 99 per cent of the rural population. This follows a 37-year rural electrification programme (REP) that ended in 1981 after practically all the rural villages had been electrified.[15]

Residential and commercial users were the two biggest consumers of electricity in 2017, consuming 873 GWh and 952 GWh, respectively, with industry consuming 755 GWh.[4] The Central Electricity Board (CEB) estimates that commercial demand will increase to 1,300 GWh by 2022 due to industrialization and diversification of the economy. Residential demand is estimated to increase to 900 GWh by 2022.[6]

The CEB, a parastatal body wholly owned by the Government and established in 1952, has responsibility under the Central Electricity Board Act of January 25, 1964 to prepare and carry out development schemes with the general objective of promoting, coordinating and improving electricity generation, transmission, distribution and sales in Mauritius. The CEB accounts for 40 per cent of the power produced in the country with independent power producers (IPPs) providing the remaining 60 per cent.[6] The Utility Regulatory Authority Act, which was introduced in 2005, is now in force. Once fully operational and established, the resulting regulatory authority will have control over the operation of the electricity market, including regulating third party access to the grid and playing a vital role in restructuring the sector.[15]

The private sector has an important role to play in the development of electricity facilities, such as building new plants and production facilities for energy generation. For example, the IPPs provide for the full use of bagasse as a local, renewable biomass fuel for energy generation.[15]

Small power producers can either export their excess electricity on the CEB grid or sell it directly to a third party. The legislation has been amended to facilitate this process, and, though concrete measures have yet to be implemented, Government incentives, such as the removal of a standby charge for renewable energy, have been introduced. A study commissioned by the CEB and financed by the United Nations Development Programme (UNDP) and the World Bank recommends upgrading the existing CEB power plants and electricity network to enhance integration by up to 110 MW for renewable energy as well as the use of large battery storage to increase penetration up to 150 MW.[15]

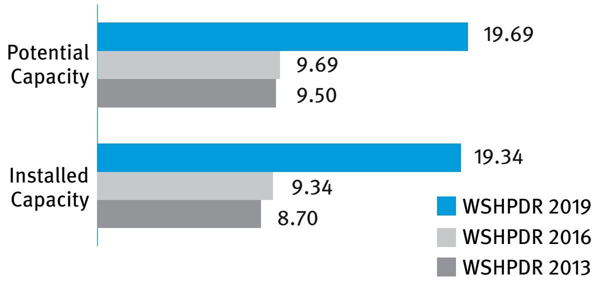
In 2018 there were 22 types of tariffs in the CEB's tariff schedule ranging from 3.16 Mauritian Rupees/kWh (US$ 0.09/kWh) for low-end residential consumers to a flat rate of 5.40 Mauritian Rupees/kWh (US$ 0.12/kWh) for high-end industrial consumers.[7] Special consideration is given to the social dimension of electricity consumption by households. For example, the CEB has in place a social tariff (Tariff 110A) providing concessionary electricity rates for customers in difficult financial situations and whose monthly consumption does not exceed 75 kWh. [15]

Existing electricity tariffs are not cost-reflective and consist of a substantial amount of cross-subsidization. There are currently difficulties in restructuring tariffs, as this can seriously affect customers' budgets (especially for subsidized tariffs). Thus, any restructuring of tariffs that is not cost-reflective must take into consideration the social dimension. Additionally, changes in the network, where customers are now also producing electricity, requires proper planning and design.[15]

Small hydropower sector overview

There is no official definition of small hydropower (SHP) in Mauritius, so this report assumes the 10 MW definition held by ICSHP. Installed capacity of SHP in Mauritius was 19.34 MW in 2018. This indicates an increase of 10 MW from the *World Small Hydropower Development Report (WSHPDR) 2016*, which is due to the availability of updated data.[14] Figure 2 offers more information on the evolution of potential and installed SHP capacities between the *WSHPDR 2013* and the *WSHPDR 2019*.

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



Source: *WSHPDR 2013*,[8] *WSHPDR 2016*,[15] Hydro4Africa[14]

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

Table 1.
Operational small hydropower plants up to 10 MW in Mauritius

Name	*Installed capacity (MW)*	*Average annual production (GWh)*	*Description*
Ferney	10 MW	Not known	The 2 Francis turbines of 5 MW each were installed in 1971 and use a gross head of 123 meters.[16]
Le Val	4 MW	4 GWh	183 metre head across Eau Bleue reservoir (4.1 million m³ capacity). Commissioned in 1961, refurbished in 2008.
Cascade Cecille	1 MW	3.5 GWh	76m head run of the river across Riviere des Anguilles rivers. Commissioned in 1963.
Reduit	1.2 MW	3 GWh	50 m head run-of-river across Terre Rouge and Cascade rivers. Fully in operation since 1906.upgraded in 1984.
La Ferme	1.2 MW	2 GWh	127 m head near La Ferme reservoir.Rebuilt in 1988, refurbished in 2008.
Magenta	0.94 MW	2 GWh	45 m head across a dam on canal near Tamarind, used for irrigation also. Commis-sioned in 1960.
Mid-lands	0.35 MW	2 GWh	Supplied by Midlands Dam (25.5 Mm³ capacity), 38.4 metre head and 88 meter penstocks.Commissioned in March 2013.
La Nicoliere	0.35 MW	1.7 GWh	Across La Nicoliere reservoir feeder canal. Commissioned in 2010.
Riche en Eau	0.2 MW	0.12 GWh	Privately owned
Bois Cherie	0.1 MW	0.48 GWh	Privately owned
Total	**19.34 MW**	**> 18.8 GWh**	

Source: CEB,[10] Hydro4Africa,[14] Water Power[16]

There are 10 existing SHP plants with a total installed capacity of 19.34 MW.[14] The La Nicoliere Feeder Canal Hydro was commissioned in 2010 and the Midlands Dam Hydro in March 2013. The remaining plants have a mean age of about 50 years with the oldest being the Reduit plant, which became fully operational in 1906. Le Val and La Ferme were both refurbished in 2008 (Table 1). Fresh rehabilitation work is now being undertaken in the latter plant as well as at Le Val/ Eau Bleue. The project for a SHP at Bagatelle Dam has been put on hold due to the apparent unavailability of financial support (100 to 350 kW proposal). At Riviere des Anguilles there is also the prospect of a SHP once the works on the dam are completed.[15]

Additionally, there are also two private power stations, Riche en Eau (200 kW) and Bois Cherie (100 kW), which brings the total installed capacity for SHP up to 10 MW to 9.34 MW. In total, SHP of less than 10 MW represents 20 per cent of the country's total hydropower production.

There are no existing studies to give an accurate figure of SHP potential in the country. Nonetheless, the CEB did commission a new station at Bagatelle Dam with a capacity of 350 kW. Once it is fully operational, it will bring the total potential capacity up to at least 19.69 MW. Aside from this planned station, it is believed that all significant hydropower has already been developed. There remain, however, a number of opportunities for mini- and micro-hydropower plants that the Government is keen to develop. To achieve this objective and as part of the CEB Integrated Plan 2013-2022 (see below), the CEB initiated a feasibility study in 2014 to identify potential sites for the development of micro- and mini-hydropower projects.[15] This study is yet to be completed.

The Government is also encouraging the set-up of mini-hydropower plants under the Small Scale Distributed Generation (SSDG) scheme although none have been commissioned so far.[15]

Renewable energy policy

The long-term vision of the Government of Mauritius is to reduce its dependency on imported energy by increasing the use of renewable sources. According to the Long-Term Energy Strategy 2009–2025 the Government aims to increase the share of renewable energy production to 35 per cent by 2025.[9,15]

In 2008, the Mauritius Sustainable Island (Maurice Ile Durable) project was launched to provide grants for the promotion of clean energy. As part of this initiative, a tax on fossil fuels was imposed to subsidize renewable energy and sustainable development projects. The tax, imposed in 2008, was doubled in 2011 to 0.30 Mauritian Rupees (US$ 0.01) per kg of coal, liquid petroleum gas (LPG) and other petroleum products. A carbon tax was also imposed on vehicles from July 2011.[15] Both have now been removed.

The Integrated Electricity Plan (IEP) 2013-2022 provides a 10-year plan of the energy sector in Mauritius. According to the IEP, approximately 70 MW of solar and wind energy are currently in the planning stage and tenders will be issued for renewable energy as per the following schedule: 10 MW solar in 2016, 20 MW wind in 2017, 10 MW solar in 2019, 20 MW wind in 2020 and 10 MW solar in 2022.[15] These proposals have in some cases been delayed, and other calls for proposals have been made, but their outcomes are not known to the public.

In December 2010, the CEB, in collaboration with the Ministry of Energy and Public Utilities, launched the SSDG scheme, through which small IPPs are given the opportunity to produce their own electricity from renewable sources (solar, wind or hydropower) and export any surplus to the grid. The scheme allows small IPPs to generate electricity on a small scale, with a maximum individual capacity of 50 kW. Additionally, the Medium Scale Distributed Generators (MSDG) scheme gives special feed-in tariffs (FITs) for capacities above 50 kW but lower than 4 MW. As part of these schemes, a new grid code to ensure a safe two-way flow of electricity and attractive FITs was drafted and implemented.[15]

The FITs, shown in Table 2, are applicable for the first 15 years of production. SSDG owners must consume one third of the energy produced or the FIT for the following year will be reduced by 15 per cent.[9] The initial target of 2 MW installed capacity, which was reached in May 2011, consisted of 1 MW for residential consumption (195 applicants) and 1 MW for commercial and industrial consumption (76 applicants). A second phase of the SSDG was launched in December 2011 for a total capacity of 1 MW.[10] According to the CEB, this target was also achieved, and, in 2012, an additional 2 MW was allocated under the SSDG scheme for educational, charitable and religious institutions. Applications are still being processed.[15]

Table 2.
Feed-in tariffs for renewable energy sources in Mauritius

Size	*FIT tariffs (MUR (US$)/kWh)*		
	Hydropower	*Photovoltaics*	*Wind*
Micro (up to 2.5 kW)	15 (0.28)	25 (0.47)	20 (0.38)
Mini (2.5 - 10 kW)	15 (0.28)	20 (0.38)	25 (0.47)
Small (10 - 50 kW)	10 (0.19)	15 (0.28)	10 (0.19)

Source: Central Electricity Board,[11] *WSHPDR 2016*[15]

In March 2015, a new target of 50 per cent was confirmed by the Minister of Energy and Public Utilities.[12,13] But, in concrete terms, this has yet to be translated into action or even confirmed policy-wise. The budget also announced the establishment of the Mauritius Renewable Energy Agency to promote the development of renewable energy. Additionally, investment in solar and other renewable energies will be eligible for financing and other incentives under a small and medium enterprise financing scheme. A land conversion tax exemption for all renewable energy project producers was also declared.[15]

Despite the initiatives outlined above, challenges still remain for the development of renewable energy. The cost of importing fossil fuels for energy generation in Mauritius is significant. Renewable energy sources are not yet widely used and energy consumption in buildings and industry is often inefficient. The building sector alone accounts for about 78 per cent of total national carbon emissions. However, the cost of generation from renewable energy is comparatively higher (especially for solar and wind) than that of conventional sources of power generation. This is largely due to the initial investment cost and very low capacity utilization factor.[15]

However, these costs may decrease as competition among suppliers of renewable technologies on the world market increases and new improved products with higher efficiencies are developed. Other fiscal incentives must be introduced to counter the high cost of renewable energy production, such as decreasing the tax on materials needed for construction as well as additional incentives similar to the SSDG scheme and taxation charges on pollution to make renewable sources more attractive.[15]

Legislation on small hydropower

The Environment Protection Act (EPA) 2002 provides the legislative and administrative framework for the protection and preservation of the environment and, according to the CEB Integrated Plan 2013-2022, an Environment Impact Assessment (EIA) licence needs to be obtained for all mini- and micro-hydro plants.[15]

Barriers to small hydropower development

Hydropower in Mauritius has been almost fully developed. However, there is potential for mini- and micro-hydropower plants and opportunities to improve storage capacity for industrial, agricultural and residential purposes, particularly at peak-hours. Opening the electricity market to independent producers has been successful in promoting production of electricity from renewable sources. Despite this, more financial incentives are required to further reduce the cost of all renewable energy sources including SHP.[15]

General barriers include the following:
- Topography of the island is almost flat;
- Cost of constructing dams and hydropower plants is high;
- Lack of proper infrastructure to access potential sites;
- Difficult to expand existing dams;
- Seasonal fluctuations affecting rainfall;
- Limited catchment areas;
- Inefficient management of water leads to competition with domestic use;
- Impact on environment from building hydropower plants (on residents as well as flora and fauna);
- High cost of equipment;
- Climate change is also a major challenge for all renewable energies, especially for hydropower, as changes in the predictability of rain patterns adversely affects generation.[15]

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1.1.7

Mozambique

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Key facts

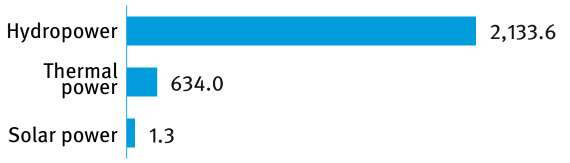
Population	29,668,834[1]
Area	799,380 km[2]
Climate	The weather along the coast of Mozambique is sunny and warm, although the southern areas are typically cooler than the northern ones. The summer months (October to April) are rainy, humid and very hot. The winter months (April to September) are cooler and drier. Coastal temperatures during the day average between 24 °C and 27 °C and can rise up to 31 °C.[2]
Topography	Mozambique is a topographically diverse country. The Zambezi River divides it into distinct northern and southern halves. The north has mountainous regions and plateaus, the Livingstone-Nyasa Highlands, the Shire (or Namuli) Highlands and the *Angónia* Highlands in the north-east. The westernmost regions are particularly mountainous. South of the Zambezi are the more fertile plains, most notably in the area directly surrounding the river.[2]
Rain pattern	Rainfall varies greatly between regions and areas of the country. The north-eastern coast is the hottest and most humid, with average rainfall of 1,000 mm to over 2,000 mm. The annual average precipitation for the whole country is 1,032 mm, and the rainy season lasts from October to April. Average rainfall ranges from 800 to 1,000 mm along the coast. The rainfall decreases inland, reaching 400 mm at the border with South Africa and Zimbabwe.[2]
Hydrology	Mozambique has 104 river basins that drain the western highlands into the Indian Ocean or the Mozambique Channel in the east. The Zambezi basin is one of the largest river basins in Africa and the most important to Mozambique. It accounts for roughly 50 per cent of the surface water resources of the country and approximately 80 per cent of its hydropower potential with the Cahora Bassa dam. Water flow tends to fluctuate, owing to the rainy and dry seasons. The rivers overflow between January and March and slow in June and August. The two main lakes are Lake Niassa (Lake Malawi) and Lake Chirua (Lake Chilwa), both of which are shared with Malawi.[2]

Electricity sector overview

In Mozambique, the Ministry of Mineral Resources and Energy (MIREME) is responsible for policy-making and supervising the country's energy sector. The Conselho Nacional de Electricidade (CNELEC, National Electricity Council) is the regulatory authority for electricity. Electricidade de Moçambique (EDM, Electricity of Mozambique) is a state-owned utility tasked with generation, transportation and distribution of electricity throughout the country. The largest electricity producer is Hidroeléctrica Cahora Bassa (HCB), a state-owned independent power producer (IPP), which is responsible for the operation of the Cahora Bassa hydropower scheme (2,075 MW).[3,4]

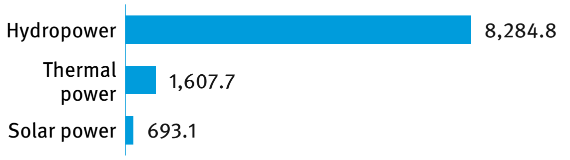
The total installed capacity in Mozambique in 2016 was 2,789 MW, of which hydropower accounted for 77 per cent, thermal power for almost 23 per cent and solar power for 0.05 per cent (Figure 1).[5] Available capacity was, however, slightly lower at 2,648.1 MW, including 2,106.8 MW of hydropower capacity, 540 MW of thermal power and 1.3 MW of solar power.[5] Electricity generation was at 10,586 GWh in 2016, 78 per cent coming from hydropower, 15 per cent from gas-fired plants and the remainder from solar power (Figure 2).[5]

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



Source: MIREME-DNE[5]

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



Source: MIREME-DNE[5]

The energy sector in Mozambique, which comprises all forms of primary and transformed energy sources, involves the following stakeholders:

- Electridade de Moçambique (EDM);
- Hidroeléctrica de Cahora Bassa (HCB);
- Companhia Eléctrica do Zambeze (CEZA);
- Redes Energéticas Mozambique Nacionais (REN) of Portugal;
- Mozambique Transmission Company (MOTRACO), which supplies aluminium smelters;
- Fundo Nacional de Energia (FUNAE), which involves mostly in off-grid generation;
- Instituto Nacional do Petróleo (INP);
- Companhia Moçambicana de Hidrocarbonetos (CMH);
- PPs.

Following the Electricity Law (1997) that allowed the participation of the private companies in the electricity sector, the development of IPP participation in the power generation sector has been underway. Currently, there are three IPPs with power purchase agreements (PPAs) with EDM: Central Termoelectrica de Ressano Garcia (CTRG) (175 MW), Gigawatt (110 MW) and Kuvaninga (40 MW). Furthermore, the Temporary Power Generation Company (Aggreko) operates on a short-term contract, while Ncondezi, Moatize, Vale and others are in varying stages of progress with their respective plans to develop generation capacities.[6,7,8]

The current policy objectives of the Government and EDM are focused on rural electrification and increasing the number of new users on a continuous basis. Grid extensions to rural areas and intensification in urban areas enabled the connection of all provincial capitals in 2007 and 120 district capitals in 2014.[8] This resulted in an increase in the electrification rate, from 11 per cent in 2004 to 24 per cent in 2016.[9] By 2018, a total number of approximately 1.5 million customers in all regions and provinces of the country were connected to the grid.[6]

Table 1.
Electricity tariffs in Mozambique (US$/kWh) as of February 2017

Tariff	*0-100 kWh*	*101-200 kWh*	*201-500 kWh*	*>500 kWh*	*Prepaid*
Social	0.015	-	-	-	0.015
Household	-	0.033	0.044	0.046	0.042
Farming	-	0.033	0.047	0.052	0.046
General	-	0.037	0.053	0.058	0.053
Flat Rate	-	1.070	1.070	1.070	-

Source: RECP[4]

However, the grid extension has not increased the diversity in the energy mix and the country still has a high degree of reliance on a single energy source, namely, hydropower. Week-long blackouts due to natural disasters and operating failures have caused substantial losses to the national economy. In addition, Mozambique suffers from administrative, transmission and distribution losses totalling 27 per cent of power generated. This further exacerbates the country's increasingly acute energy shortage.[6,10]

The Government is currently undertaking projects to strengthen the transmission network, known as the backbone project, to increase transmission efficiency of electricity from the generation areas, namely Tete, to the load centres along the coast. The extensive new power transmission infrastructure spans more than 5,360 km with transmission capacity of approximately 5,500 MVA across the national territory. The improvements will also increase exports to South Africa and other neighbouring countries, in particular once several large new hydro projects are completed, namely Mphanda Nkuwa Hydropower (1,500 MW), HCB North Bank (1,245 MW) and a number of other initiatives such as Lupata (600 MW), Boroma (200 MW) and Lurio (120 MW).[6,11]

The rules and the prices used by the EDM are set out in the Tariff System for the Sale of Electric Energy in Decree number 29/2003 of July 23, 2003. According to this decree, the tariff system sets prices by taking into account the voltage, the tariff option and the period of energy supply. The legislation defines three kinds of voltages: low-voltage (1 kV), mid-voltage (1 kV - 66 kV) and high voltage (from 66 kV).[4,6]

Small hydropower sector overview

Mozambique classifies small hydropower (SHP) as plants with an installed capacity up to 25 MW. However, for the purposes of this report, SHP is defined as up to 10 MW. In 2016, the total installed capacity of SHP plants in Mozambique was 3.37 MW, while available capacity stood at only 2.77 MW.[5] Compared to the *World Small Hydropower Development Report (WSHPDR) 2016*, the installed capacity up to 10 MW has increased by almost 48 per cent, while the potential capacity has remained unchanged (Figure 2). It should be noted that under the Mozambican definition, the 16 MW Corumana plant would be included, bringing installed capacity of SHP up to 19.37 MW.[5,8]

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

Source: MIREME-DNE,[5] *WSHPDR 2016*,[8] *WSHPDR 2013*[12]

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

The country's greatest hydropower potential lies in the Zambezi River basin at sites such as Cahora Bassa North and Mphanda Nkuwa. So far, over 2,000 MW of generating capacity has been developed. Other than the 16 MW Corumana plant, there are several SHP installations, including Lichinga (0.75 MW), Cuamba (1.1 MW) and numerous mini- and micro-plants. In terms of rural electrification, SHP plants are a promising solution for inclusive and sustainable development as they are able to provide affordable and efficient electricity to isolated and remote locations.[3,8,13]

SHP plants in Mozambique are particularly concentrated in the centre of the country, more specifically in the Provinces of Manica, Tete and Zambézia. The main players involved in SHP development are FUNAE, the German Corporation for International Cooperation (GIZ) and the non-governmental organization Practical Action.

FUNAE is responsible for five mini-hydropower plants: Rotanda (630 kW), Majaua (595 kW), Muôha (100 kW), Sembezeia (62 kW) and Chiuraírue (23.1 kW). The Majaua plant has recently been rehabilitated, which included the installation of generation equipment, the switchboard's electrical components and the command and control panels, as well as the extension of the medium-voltage lines to the settlements of Maia, Chimboa, Manhapwa and Gurgunha and the primary and secondary low-voltage grids. The Sembezeia plant was completed in 2015 and is now fully operational, with a 62 kW capacity for supplying consumers and public lighting. The Rotanda hydropower plant with a capacity of 630 kW was built and tested in 2015. It is connected through a sub-station to the local EDM grid, which is further connected to the ZESA network in Zimbabwe. FUNAE has also carried out feasibility studies, in particular for the mini hydropower plants of Mavonde (900 kW) in Manica District.[14]

GIZ has financed and implemented 11 micro-hydropower plants in the Province of Manica, with a capacity of 20-30 kW each. These plants are managed by local private entrepreneurs. GIZ also provided technical support for the installation of another six micro-hydropower plants, of which four were financed by Practical Action, one by private funds and one by FUNAE. Furthermore, in the Province of Manica, the Association Kwaedza Simukai Manica (AKSM), in partnership with VSO, GIZ and Practical Action, implemented 15 pico-hydropower plants.[14]

Renewable energy policy

Mozambique is a country rich in natural and renewable energy resources. In addition to its vast hydropower potential, there are several sources of renewable energy that could change the energy mix in the country: a large portion of the territory is suitable for efficient solar energy production; biomass is plentiful, in particular agriculture waste such as rice husks in Quelimane; wind potential is greatest in the south; and promising geothermal sources in the north. All these could be utilized to meet the ever-increasing electricity demand.[8,15]

The legal framework for foreign investment and renewable energy is currently undergoing review. The applicable laws are the Investment Law (Law 3/1993 and Decree 43/2009), Electricity Law (Law 21/1997, Decree 8/2000 and Decree 42/2005), Energy Policy (Resolution 5/1998 and Resolution 10/2009) and Private Public Partnership (Law 15/2011 and Decree 12/2012).[10] As of November 2018, the Government was reviewing an update of the Electricity Law, which is aimed at accelerating universal access to electricity by 2030.[16]

The Government's renewable energy policies have helped spur development within the energy sector, which are by and large issued from the National Directorate of Energy. The target of increasing the electrification rate to 50 per cent by 2024, and objectives established within the SE4ALL framework, could potentially double the amount of renewable energy utilized in the country.[8]

In conjunction with the Government's Poverty Reduction Strategy, the National Strategy for Renewable Energy and the Green Economy Action Plan aim to increase private sector competitiveness and develop or improve current infrastructure. In line with these policies, the Sustainable Energy Fund for Africa (SEFA) approved a US$ 740,000 grant for technical assistance in enabling private investments in the renewable energy sector.[8,15]

Legislation on small hydropower

The National Water Policy (PNA, 1995) stipulates that hydropower installations are required to have a water use concession. In addition, the 1995 policy used two mechanisms for implementation, the Rural Water Transition Plan and the Implementation Manual for Rural Water Projects (MIPAR). In 2007, the PNA was revised and became the Water Policy (PA). The revision was aimed at meeting the United Nations' Millennium Development Goals and included private investment in local water management and utilization.[8,17] The Water Policy mentions the use of water resources for standalone and dam-connected hydropower purposes and states that small- and medium-scale hydropower facilities should be encouraged for off-grid electricity in remote areas, extension of the national electricity grid production and transmission capacity, as well as economic development in general.[8,18]

Barriers to small hydropower development

The challenges hindering the development of SHP in Mozambique include:

- Lack of a consolidated legal framework;
- Absence of a strategy defining governmental investment plans for hydropower plants;
- Limited information about the number and location of the existing plants as well as potential sites;
- Lack of local technologies;
- Underdeveloped market.[8,14]

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1.1.8 Réunion

Gaelle Gilboire, Energie Réunion

Key facts

Population	850,996 [1]
Area	2,504 km^2
Climate	In general, the weather in Réunion is tropical and humid. From November to April, the season is warm and humid, while the drier season occurs from May to October.[3] The summer, which stretches from December to March, has a mean temperature of 26 °C on the coast. Winter, from April to November, has an average temperature of 20 °C on the coast. At higher altitudes, temperatures drop significantly.[8]
Topography	Réunion island is the result of volcanic activity, with mountain peaks in the interior and two distinct volcanoes: the Piton des Neiges (Snow Peak), which is now extinct, and the Piton de la Fournaise (Furnace Peak), which is younger and more active. The Piton des Neiges is also the highest point on the island at 3,072 metres above sea level.[8]
Rain pattern	Summer is the wettest season and February the wettest month, with an average of 304 mm of rainfall. October is the driest month with an average of 75 mm of rainfall.[9]
Hydrology	A large number of rivers flow through Réunion, including the Rivière des Marsouins that runs abundantly all year round. Other notable rivers are the Sainte Suzanne, Grand-Bois, Salazie and Mafate Rivers.[8]

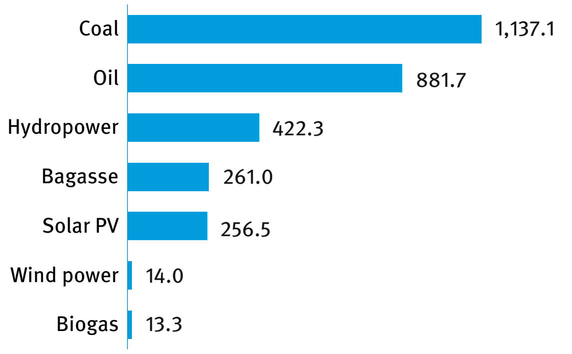
Electricity sector overview

Réunion is an overseas department and an administrative region of France. Réunion aims to cover its comprehensive electricity production via renewable energy sources by 2030.[3] The French company Électricité de France (EDF) is the electricity provider on the island.

In 2017, the total electricity production was 2,986 GWh. Electricity was generated from different sources: thermal and renewable sources, with coal dominating the generation mix at 38 per cent of total generation (Figure 1).[5] Compared to 2016, the share of renewable energy sources decreased by 1.6 percentage points to 32.4 per cent. Electricity production from all renewable energy sources decreased, which was caused by weather conditions. The only exception was bagasse, which showed an almost 7 per cent increase compared to 2016, due to climatic conditions in the winter months favourable for the growth of sugar cane.[5]

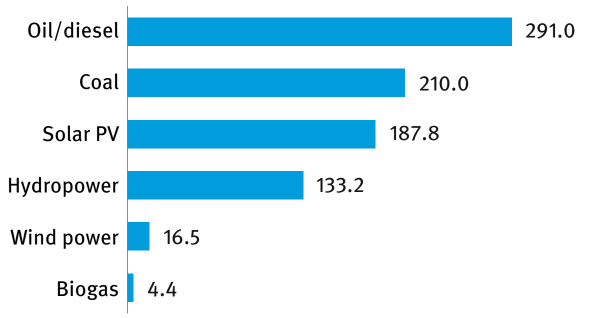
Total installed capacity as of December 2017 was 843 MW, of which oil- and diesel-fired plants accounted for 35 per cent, coal-fired plants for 25 per cent, solar PV plants for 22 per cent, hydropower for 16 per cent, wind power for 2 per cent and biogas for 1 per cent (Figure 2).[5] Until 2011, hydropower was the most utilized renewable energy source, as it was one of the first renewable energy sources developed on the island. However, since 2012, Réunion has invested in the development of different renewable energy technologies, and now solar photovoltaics is more developed than hydropower, with installed capacities of 187.8 MW and 133.2 MW, respectively.[5]

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



Source: Energies Réunion[5]

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



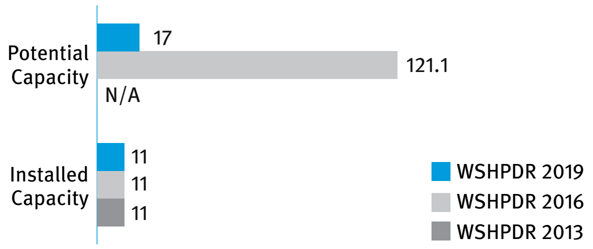
Source: Energies Réunion[5]

Basic electricity tariffs vary according to the kVA power of the electronic devices used and the time of the day when they are used. As of 2018, residential tariffs varied from 0.143 EUR/kWh (0.167 US$/kWh) to 0.137 EUR/kWh (0.160 US$/kWh).[15]

Small hydropower sector overview

Réunion, in accordance with French legislation, defines small hydropower (SHP) as hydropower plants up to 10 MW. The total SHP installed capacity in Réunion is approximately 11 MW (Table 1).[5] The total untapped hydropower potential in the island is estimated at 121.1 MW, of which 59.10 MW is difficult to be developed, 50.53 MW can be developed under strict conditions and 11.47 has no limitations for development.[7] As far as SHP is concerned, the island has only 6 MW of untapped potential, making it 17 MW in total.[7] Compared to *the World Small Hydropower Development Report (WSHPDR) 2016*, installed capacity remained unchanged as no new projects were developed, while potential capacity decreased, which is due to access to more accurate data (Figure 3).

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



Source: Energies Réunion,[5] Hydropower Plan,[7] *WSHPDR 2013*,[10] *WSHPDR 2016*[14]

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

Hydropower is produced at Rivière de l'Est (79 MW), Takamaka I (17 MW) and II (26 MW), Bras de la Plaine (4.6 MW) and Langevin (3.6 MW), Bras des Lianes (2.2 MW) power plants as well as Picocentrale RT4 (0.2 MW), for a combined capacity of 133.2 MW.[5] Though the SHP potential has been mostly tapped, there are still a number of potential sites where micro-hydropower projects can be installed.[14]

Table 1.
Installed small hydropower plants

SHP plant name	*Installed capacity (MW)*
Bras de la Plaine	4.6
Langevin	3.6
Bras des Lianes	2.2
Picocentrale HRT4	0.2
Total	**10.6**

Source: Energies Réunion[5]

Renewable energy policy

Act No. 2015-992, Article 1, of August 17, 2015 lays down the guidelines for energy policies and renewable energy for French overseas departments.[11] It states that overseas departments should be energy-autonomous by 2030, with an intermediate goal of 50 per cent of renewable energy in the energy mix by 2020. In addition, incentive mechanisms are also in place to encourage the development of renewable energy, including tax exemption, direct subsidies and feed-in tariffs (FITs) controlled by EDF.

In 2017, Réunion Island Regional Council and the Government of France defined the energy policy until 2023 for the island. This programme gives the development objectives for each renewable energy source for the period from 2018 to 2023 in order to achieve electric autonomy by 2030. The programme takes into account population and electricity consumption growth, with objectives in demand-side management as well. In this document, the objective for hydropower is to increase the installed capacity by 0.5 MW in 2018 (compared to 2014) and by 39.5 MW in 2023. Unfortunately, the project of a new 39 MW turbine on which this objective was based will not be realised.[12] This document is currently being reviewed to give new objectives for 2023 and 2028 for Réunion on renewable energy, demand-side management and transportation.

Barriers to small hydropower development

The main barriers to SHP development are:

- Costly technology due to the insularity of the island and the related costs of transportation and taxes, which obstructs contractors' willingness to undertake financial risks and invest in Réunion;
- Climatic variations and destruction coupled with volcanic activity are other risk variables of the island that investors and contractors need to face;
- Réunion is classified as a World Heritage Site, under the United Nations Educational, Scientific and Cultural Organization (UNESCO), which has two main consequences: first, environmental impact assessments are stringent; and second, the price of land per square metre has experienced a significant increase, affecting initial investment expenditures;
- Ineffective coordination between local and overseas authorities prolongs the implementation process for project owners;
- Lack of local technical support;
- Lack of information and contradictory sources, slowing down the process of development.[14]

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1.1.9

Rwanda

Robert Nyamvumba, Ministry of Infrastructure; Daniel Klinck, East African Power; Fredrick Kazungu, Carine Mukashyaka, Philbert Tuyisenge and Papias Karanganwa, Rwanda Electricity Group

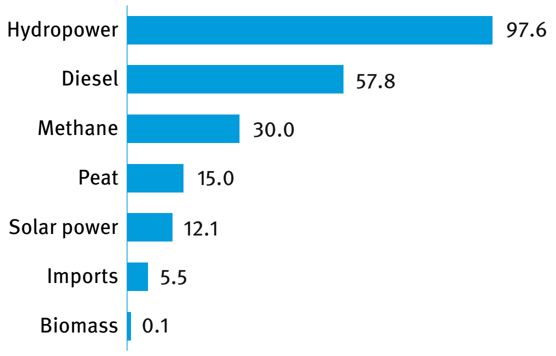
Key facts

Population	12,208,407[1]
Area	26,338 km[2]
Climate	Rwanda has a temperate tropical highland climate, with lower temperatures than are typical for equatorial countries due to its high elevation. The capital city, Kigali, situated in the centre of the country, has a typical daily temperature range between 12 °C and 27 °C, with little variation throughout the year. A long rainy season lasts from February to May and a short one from November through December.[2]
Topography	Rwanda is characterized by a topography that gradually rises from east to west. In the east, there is an average altitude of 1,250 metres above sea level, increasing to altitudes ranging between 2,000 and 3,000 metres in the west. The main features are the Virunga volcano range in the north-west, which is home to the country's highest point, Mount Karisimbi, at 4,507 metres and the Congo-Nile Ridge stretching from south-west to north-west and culminating at 2,918 metres above sea level.[3]
Rain pattern	The general climatic pattern reflects two rainy seasons and two dry seasons during the year. The average annual rainfall is 1,200 mm, however, it varies from region to region. In the eastern plateau and lowlands of the west, the average annual rainfall is 700 mm to 1,400 mm; in the central plateau, it is 1,200 mm to 1,400 mm; and in the high-altitude region in the west, it is 1,300 mm to 2,000 mm. The rainfall regime strongly influences the hydrological regime. There are floods during the rainy season, which ordinarily is from February to May, and they subside during the long dry season from June to September.[4]
Hydrology	Rwanda is a landlocked country located within the Great Lakes region. The Congo Nile Ridge divides the country's waters into two principle basins. The Congo basin to the west constitutes 67 per cent of the land area and the Nile basin in the east constitutes 33 per cent of the land area. The largest lake is Lake Kivu on the western border with the Democratic Republic of the Congo.[3]

Electricity sector overview

As of June 2018, the installed capacity was 218.1 MW, of which 47.2 per cent came from the thermal power plants fired by oil, peat and methane, 44.8 per cent from hydropower plants, 5.5 per cent from solar power, 2.5 per cent from imports and less than 0.05 per cent from biomass (Figure 1).[5]

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



Source: EDCL[5]

The economy of Rwanda has been steadily growing at an average rate of 8.5 per cent. The Government plans to increase this to 11.5 per cent by 2020. In order for this target to be met, the energy sector needs to be improved through access to affordable electricity from modern sources.[6,7] Rwanda has one of the lowest energy consumption rates per capita in the world. Electricity accounts for approximately 4 per cent of the primary energy sources, with biomass contributing approximately 85 per cent.[6,7]

As of July 2018, the nationwide electrification rate reached approximately 46 per cent, with 35 per cent of households connected to the national grid and 11 per cent having access through off-grid systems (mainly solar). However, the electrification rate also varies significantly across regions – from 97 per cent in Kicukiro District to 27 per cent in Nyamagabe District. The Government has set a target to increase the national electrification rate to 100 per cent by 2024 and to provide 100 per cent electrification to productive users by 2022. To achieve this goal, it is planned to add 500,000 new connections every year, including 200,000 on-grid and 300,000 off-grid. The Government particularly focuses on the off-grid connections, encouraging households located far away from the planned national grid coverage to use cheaper alternatives, such as mini-grids and solar photovoltaics (PV).[5,8]

Current projections for the demand are in the range between 377 MW and 473 MW by 2024.[9] To meet the growing demand, a number of projects are currently under development, including large-scale peat and methane projects and regional and local hydropower plants. Improving energy efficiency by reducing losses in transmission and distribution from the current level of 19 per cent to 15 per cent is also seen as a way of addressing the demand issue.[5,10] The Government is prioritizing the development of different generation sources in order to reduce perceived delivery risks, lay the groundwork for more private sector participation and achieve environmental sustainability objectives.[10,11] In particular, the private sector is seen as helping to supply rural households by means of decentralized technologies, such as solar lighting and village grids.[12]

Rwanda has approximately 715 km of 110 kV and 425 km of 220 kV high-voltage (HV) transmission lines, 5,590 km of medium-voltage lines (MV, 30 kV, 15 kV and 6.6 kV) and 10,572 km of low-voltage lines (LV, 380 V and 220 V).[5,13,14] The electric network is interconnected with the networks of Burundi, the Democratic Republic of the Congo and Uganda. There presently is no inter-linkage with the United Republic of Tanzania. Power flows between Rwanda, Burundi and the Democratic Republic of the Congo are managed by the International Society for Electricity in the Great Lakes Region (SINELAC). According to the Electricity Development Strategy for 2018-2024, Rwanda intends to extend its grid by 5,600 km of medium-voltage lines and 8,050 km of low-voltage lines.[10] The transmission network of the country is characterized by high consumption of electricity in Kigali, which corresponds to approximately 50 per cent of the total national consumption over the evening peak, while a significant share of power generation capacity is concentrated in the south-west of the country. In order to transport all the power generated in this region, the 220 kV transmission line Bwishyura – Rubavu – Shango was completed. By 2024, it is also planned to complete a 220 kV ring (Bwishyura – Kigoma – Rwabusoro – Rilima – Shango – Rubavu – Bwishyura) and a 110 kV ring network (Jabana – Gikondo – Mont Kigali – Gahanga – Ndera – Gasogi – Birembo - Gikondo).[10]

The country's principle legislation for the electricity sector, the revised 2018 Electricity Law, governs the activities of electric power production, transmission, distribution, and trading both within and outside the national territory of Rwanda. The law outlines the liberalization and regulation of the electricity sector, the development of power supply for all population categories and for all the country's economic and social development sectors, the creation of economic conditions enabling electric power sector investments and respect for the conditions of fair competition and for rights of users and operators.[7]

The Ministry of Infrastructure (MININFRA) is responsible for the overall coordination of activities in the energy sector, setting policies, strategies, planning and monitoring of different programmes. MININFRA also plays an important role in attracting private sector investment and coordinating support of development partners. Following the reforms in 2013, the Rwanda Energy Group (REG) took over the energy operations formerly under the Energy Water and Sanitation Authority (EWSA). REG is split into two subsidiaries: the Energy Utility Corporation Limited is responsible for generation, transmission and distribution networks and sale of electricity, while the Energy Development Corporation Limited is in charge of new generation, transmission and electricity access development projects.[7]

The role of the private sector has been limited in the past but the Government is currently encouraging electricity production through public-private partnerships, including in the hydropower sector, to support management and construction. The Government has been supporting private investment in the sector through the following initiatives:
- The Government provides transmission access to all power projects at its own cost;
- Transmission line and road access to eligible projects;
- Provision of road access and all infrastructures needed to develop projects;
- Generous fiscal and non-fiscal incentives including tax exemptions on power equipment;
- The Government acquires land for power projects at its cost or compensates private developers for land acquisition;
- Direct operating cost support by paying for fuel imports/ equipment rental or exempting import tax;
- Capital expenditure support by seeking external funds as well as funds allocation from budget.[7]

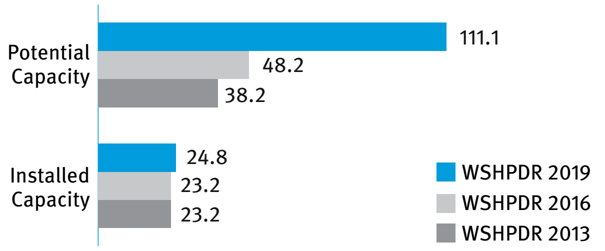
The Rwanda Utilities Regulatory Authority (RURA) is the industry regulator responsible for setting and approving electricity tariffs, in consultation with MININFRA. Other key functions of RURA include the following:
- Conducting all technical regulatory activities for the power production, transmission and distribution sectors;
- Issuing permits and licences to firms that satisfy licensing requirements;
- Monitoring, evaluating and ensuring the quality of the technical services provided by the electric utility;
- Ensuring both compliance to the adopted standards and a fair competition between electricity operators;
- Promoting the utilization of renewable energy resources in rural areas.[7]

Rwanda has some of the highest electricity tariffs in the region which is compounded by its low purchasing power. The Electricity Law empowers RURA to set and approve electricity tariffs, in consultation with MININFRA and pursuant to laws and regulations in force. The law also allows for cost-based tariffs to ensure adequate return on investments made by licence holders and for performance-based pricing and benchmarking.[7] The current electricity tariff for residential users ranges from 89 FRW/kWh (0.10 US$/kWh) to 210 FRW/kWh (0.24 US$/kWh) depending on the level of consumption. Following the tariff review in August 2018, the prices of electricity for industrial users were lowered and are currently between 80 FRW/kWh (0.09 US$/kWh) and 126 FRW/kWh (0.13 US$/kWh) depending on the annual consumption.[15]

Small hydropower sector overview

Small hydropower plants (SHP) in Rwanda are defined as plants with an installed capacity up to 5 MW. Current installed capacity is 24.8 MW, with an additional potential of at least 86.4 MW (based on the projects under development and identified sites), indicating that some 22 per cent has been developed.[16,17] In comparison to data from the *World Small Hydropower Development Report* (*WSHPDR*) *2016*, the installed and potential capacities have increased by 7 and 131 per cent, respectively (Figure 2).

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



Source: *WSHPDR 2016*,[7] REG,[16] East African Power,[17] *WSHPDR 2013* [18]

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

Current installed SHP capacity represents approximately 25 per cent of the county's total hydropower capacity. Table 1 gives details of 24 of the country's operational plants, the majority of which are privately owned. On 27 August 2015, MININFRA announced it had leased 22 SHP projects located in the northern and western provinces to private investors to spur the country's hydroelectric energy programme. According to the energy experts at MININFRA, the plants would add approximately 24.6 MW of hydroelectric energy to the national grid.[7,19]

The most significant resource assessment conducted to date is the Rwandan Hydropower Atlas. This was conducted in 2010 and it found that the majority of potentially feasible sites would be rated between 50 kW and 1 MW in capacity. The study estimated a potential capacity of 96 MW from micro-hydro projects alone. Feasibility studies have been completed or are under way for a number of sites, representing at least 32 MW of technically viable new capacity. In addition, over 192 sites have been identified for pico-hydropower plants with capacities below 50 kW. An ongoing comprehensive assessment of hydropower resources on the Akanyaru River basin, located on the border between Rwanda and Burundi, adopts this approach. These resources can be developed in cascade form, with 11 domestic sites and three shared sites recommended for further feasibility analysis. Based on the preliminary estimates, these projects could potentially augment the country's total installed capacity by over 25 MW.[7] Currently, there are 55 SHP projects in various stages of development, 32 projects with finished feasibility studies and eight further potential sites. The combined capacity of these is 86.38 MW.[1]

The Government of Rwanda has integrated private-sector development into its policies for expanding electricity supply and is planning to privatize all publicly-funded micro-hydropower plants, while private small and medium-sized businesses are increasingly taking the lead in negotiations with the national energy provider and government agencies. To boost the private-sector participation in the hydropower energy programme, several Initiatives, including the Private Sector Participation in Micro Hydro Power (PSP Hydro) project, the Energy Small and Medium Enterprise (ESME) Trust Fund and the National Climate Change and Environmental Fund (FONERWA), have been developed.[7]

Table 1.
Operational small hydropower plants in Rwanda

Giciye 1	4.00	Rwanda Mountain Tea
Giciye 2	4.00	Rwanda Mountain Tea
Mukungwa 2	2.50	Prime Energy
Rugezi	2.20	Rwanda Mountain Tea
Keya	2.20	Energicotel
Rukarara 2	2.20	Prime Energy
Gihira	1.80	Rwanda Mountain Tea
Gisenyi	1.20	Prime Energy
Nkora	0.68	Energicotel
Mazimeru	0.50	Energie Nyaruguru
Nyirabuhombohombo	0.50	AESG
Gaseke	0.50	Novel Energy Ltd
Musarara	0.44	Amahoro Energy
Nshili I	0.40	EUCL
Cyimbili	0.30	Energicotel
Mutobo	0.20	REPRO
Agatobwe	0.20	TIGER
Janja	0.20	AESG
Nyabahanga	0.20	EUCL
Gashahi	0.20	Prime Energy
Murunda	0.10	REPRO
Nyamyotsi I	0.10	Energicotel
Nyamyotsi II	0.10	Energicotel
Rushaki	0.04	Government of Rwanda
Total	**24.76**	

Source: REG,[16] East African Power[17]

PSP Hydro Project utilizes public private partnerships (PPPs) to enable small and medium-sized enterprises to install and operate sustainable micro-hydropower plants. PSP Hydro identifies and supports private firms throughout the project cycle with consulting services, training and limited co-financing. The first three privately-owned micro-hydropower plants in Rwanda, with respective capacities of 96 kW, 500 kW and 438 kW, were connected to the national electricity grid, providing electricity to more than 20,000 people. The project developers are either Rwandan companies or joint ventures between Rwandan and international companies.[7,12]

As a result of the PPP approach, 75 per cent of the investment costs were raised from private capital through equity and commercial bank loans. Rwandan banks are financing private energy projects on a commercial basis for the first time and international investors have started investing in companies supported by PSP Hydro. Policy dialogue between the Government and private sector companies supported by the PSP Hydro project has led to the establishment of a solid investment framework. PSP Hydro also supported the adoption of feed-in tariffs for micro-hydropower and the establishment of several regulations, including environmental standards and licensing procedures. When this project started in 2006, Rwanda had no private hydropower capacity. Since then, with PSP Hydro's support, the sector has developed to a point where over 20 companies are now working to provide Rwanda with the electricity it needs.[7]

ESME Trust Fund is a facility that was set up by the Russian Federation in 2009 providing US$30 million in the form of a grant facility to support small and medium-sized energy enterprises in sub-Saharan Africa. Rwanda is one of the countries selected for support under the ESME Trust Fund with a total financing of US$3.5 million. The fund is provided through the World Bank and managed by the Sustainable Energy Development Project (SEDP) under REG. The ESME Trust Fund managed by SEDP is earmarked to support capacity building to ensure quality and competitiveness of private local investors in micro-hydropower projects. This will be done through the support to business training opportunities and technical assistance to the investors in question.[7]

FONERWA is a facility that was introduced by the Government to facilitate the financing of environment and climate change projects. This facility is available to both public and private developers through in-kind support for proposal development, performance-based grants and low interest rate loans guarantees.[7]

Renewable energy policy

The SE4ALL Action Agenda of Rwanda has set a target of 60 per cent of renewable energy share in electricity generation mix by 2030. This target is far over the global target of approximately 44 per cent. By the end of the current Energy Sector Strategic Plan period, the Government of Rwanda plans to ensure universal access to clean energy, with 52 per cent connected via the grid and 48 per cent connected via off-grid technologies, mainly powered by renewable energy, in particular solar and micro-hydropower.[10]

Between 2012 and 2015, a Renewable Energy Feed-In Tariff (REFIT) scheme was conducted by EWSA in close collaboration with RURA. The scheme covered hydropower plants ranging from 50 kW up to 10 MW and located within 10 km of the transmission network. Although the policy expired after a duration of three years and has now been replaced by renewable energy tenders, this does not affect projects that signed PPAs under the scheme during that period (Table 1).[20]

Table 2.
Small hydropower feed-in tariffs in Rwanda

Plant installed capacity (MW)	*Feed-in tariff (US$/kWh)*
0.05	0.166
0.10	0.161
0.15	0.152
0.20	0.143
0.25	0.135
0.50	0.129
0.75	0.123
1.00	0.118
2.00	0.095
3.00	0.087
4.00	0.079
5.00	0.072
6.00	0.071
7.00	0.070
8.00	0.069
9.00	0.068
10.00	0.067

Source: RURA[20]

Barriers to small hydropower development

Many of the challenges facing SHP development are linked to challenges facing the electricity sector in general. These include the following:
- Limited demand;
- The cost of financing infrastructure, such as transmission lines and access roads to the potential sites;
- High tariffs due to high investment cost as a result of terrain and limited water resources;
- Low energy capacity potential due to limited available water resources;
- Insufficient and unreliable power supply through lack of generation;
- Limited access of low-income households to improved stoves and modern energy;
- Limited funds for programme development.[7]

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1.1.10 Somalia

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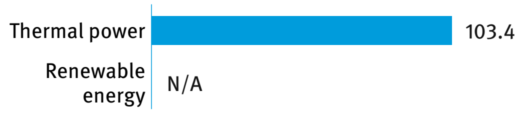
Key facts

Population	14,742,523 (est.)[1]
Area	627,340 km^2[2]
Climate	Somalia has a semi-arid to arid climate, which is determined by its location in the Inter-Tropical Convergence Zone (ITCZ).[3] Temperature ranges fluctuate between 20 °C to 40 °C in the south, with cooler temperatures along the coast and temperatures reaching as high as 45 °C in the northern coastal plains.[4]
Topography	Located on the Horn of Africa, Somalia boasts the longest coastline of any country on the continent. In the north, higher plateaus and mountains reach between 900 metres and 2,100 metres, gradually declining into a central plateau. Moving south, the region transitions into lower coastal plains and fertile agricultural areas between the Jubba and Shabelle rivers, before extending into low pastureland on the border of Kenya.[5]
Rain pattern	The major wet season (Gu) lasts between April and June, followed by the Haggai, which brings relatively cool temperatures with drier conditions on the inland plateau and light showers along the coast.[6] The Deyr rains occur from October through November, which lead into the longer dry Jilaal season that spans from December through March. Precipitation levels range from 700-800 mm per year in the Jubba and Shabelle regions to less than 100 mm per year along the northern coast.[3]
Hydrology	The majority of Somalia's water resources are dominated by surface water obtained from the Jubba and Shabelle rivers, of which 90 per cent of flows originate in the Ethiopian highlands. Total internal water resources, including both surface and ground water, average 6 km^3 per year.[5]

Electricity sector overview

As of 2015, Somalia's installed electricity capacity was 103.4 MW, down from an estimated historical capacity of 175 MW to 180 MW installed prior to the outbreak of the civil war in the early 1990s. The majority of the country's electricity is supplied by fossil fuel-based thermal generators, while a smaller subset of renewable energy is generated through solar power and wind turbines.[5] Within the energy sector as a whole, as much as 80 to 90 per cent of energy is obtained through biomass sources, with the majority share represented by charcoal. Fossil fuel usage accounts for 10 per cent of the energy mix, 2 per cent of which is produced by diesel powered generators.[7] The remaining energy share is generated through renewable sources.

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



Source: AfDB [5]

Somalia's decades long civil war has undermined the energy sector. The combination of the prolonged conflict and subsequent statelessness has significantly reduced Somalia's electrical generation capacity, namely through the destruction of electrical grids and by allowing infrastructure to fall into disrepair. Perhaps just as damaging was the effect that it had on reducing international investment, the availability of a skilled workforce and Government regulatory oversight. In recent years, an added element of concern is the security risk that Al Shabaab and other armed militia groups pose to any large-scale infrastructural projects due to their potential to inflict significant damage to Somalia's economic system.[8]

Precise and reliable data relating to installed capacity and electricity generation is difficult to obtain due to the fragmented nature of the energy sector and the sparse availability of data. The World Bank indicated that 29.9 per cent of Somalia's population had access to electricity in 2016, which translates into an estimated 270,000 to 679,073 individual connections to households and businesses.[8] In terms of overall electricity consumption, the latest estimates indicate that Somalis rank in the bottom 1 per cent of the world average at 28.7 kWh per capita.[8]

These numbers do not reflect the vast disparity that exists between rural and urban populations' access to electricity. Electrification in rural areas is limited or non-existent due to the lack of infrastructure and connection to a larger electrical grid structure (note that rural electricity access has shown gradual improvement with the added accessibility and convenience of solar PV technology which has allowed some households and businesses to access electricity on a smaller, individual scale).[8] Urban electrification varies by individual city and region, which reflects the level of infrastructure and the generating capacity of privately owned electrical companies.[5] For example, estimates of electricity access in Mogadishu and Hargeisa in Somaliland have ranged as high as 60 to 70 per cent, whereas smaller cities such as Merka only have 23 per cent access (Table 1).

Table 1.
Variation in electricity access

Region	*Electrification rate (%)*
Rural	11.2
Urban:	31.3
Larger Centers (Mogadishu/Hargeisa)	60-70
Smaller cities (Merka)	23

Source: REEEP Policy Database,[8] World Bank[9]

As a result of the weakened state of Somalia's public energy sector, the private sector has taken a more primary role in sourcing and providing electricity. Rather than large, centralized systems of power generation, the majority of Somalia's electricity is generated by small independent providers operating through local or regional companies.[11] Without Government oversight, these independent power companies have improvised their own local systems of electricity distribution but lack a coherent interconnected grid between generators which has the potential to promote more efficient and cost-effective economies of scale.[8] In addition to these independent networks, there is also a smaller subset of semi-public utility companies that provide electricity to large urban areas, but they operate on dated grid systems and are only in select cities including Hargeisa, Qardo, Berbera and Bosaso.[5]

While the flexible and adaptive nature of private sector energy companies has its advantages including accessing private funding sources in the Somali diaspora and fast mobilization, they also have distinct weaknesses. The radial system of individual electrical networks is characterized by medium- to low-voltage power supplies, which are further diminished by transmission losses of up to 50 per cent of starting power levels. Compared to other African countries, or even other fragile and conflict-affected states, this is four and two times higher than the average rate of loss, respectively.[5] This means that, on average, voltage rates typically can be 220 to 400 V, but are often as low as 150 to 220 V. As a result, most households with access only use electricity for lighting purposes or other low current appliances.

National and regional Governments are responsible for overseeing and implementing energy sector policy. In 2010, Somaliland's Ministry of Mining, Energy and Water Resources passed an Energy Policy that initiated a regulatory framework for the region. In conjunction with the Energy Policy, Somaliland has made multiple attempts to pass an Electrical Energy Act (which at the time of writing is waiting to be passed into law) which would establish a formal legal framework that would oversee tariff rates, administration, and skilled training initiatives.[12] At the federal level, no legislation has been passed that specifically addresses the electricity industry, however, in 2016 the Government partnered with the African Development Bank Group to complete an Energy Sector Needs Assessment that laid out multiple strategies aimed toward expanding Somalia's electrical capacity. One such strategy calls for increasing the supply of electricity to regional capitals through hybrid mini-grids, creating close to 200 MW of additional generating capacity over a 10-year period.[5] To date, the Government does not have the necessary staff or budget to initiate such projects and requires international donor support to accomplish their large-scale energy infrastructure goals.

This lack of regulation and oversight extends into the affordability of electricity as well. With tariffs between US$ 0.80 and US$ 1.20 per kWh, the electricity tariffs of Somalia rank among the highest in the world, especially when considering that the GDP per capita in 2017 was US$ 434.21.[5,10] Most power companies do not have a formal metering system and instead charge by the number of light bulbs or the number of appliances powered within a household or business. Some independent providers have even utilized tiered rates, meaning that some public and private institutions like mosques or government facilities pay a lower rate as compared to other consumers or nothing at all.

Table 2.
Electricity tariffs (US$/kWh)

Tariff type	*Price (US$/kWh)*
Nationwide Average	0.80-1.20
Single phase supply	0.60-1.20
Three phase supply	0.65-0.80

Source: AfDB,[5] REEEP Policy Database[8]

Regional variation in price is largely dependent upon the energy provider, the level of available infrastructure and the consumer's proximity to urban centres or primary electricity generation source. In order to supplement its energy needs and to offset high tariffs, Somalia has tapped into power surpluses in neighbouring countries. In 2014, the Federal Government entered into a shared understanding with Kenya and Ethiopia to build a hydroelectric power plant on their shared border on the Dawa River and has worked with Ethiopia to connect to their grid system in areas along the Somaliland border as well as in Puntland.[5] In the long term, there has also been discussion around utilizing the Eastern Africa Power Pool (EAPP) as a potential source of electric power, but Somalia's current load and lack of interconnection suggest limited justification for the required cost.[8]

Small hydropower sector overview

Somalia has no official definition for small hydropower (SHP). This report adopts the working definition of hydropower plants with an installed capacity of up to 10 MW. Currently there are no operational hydropower plants in the country; however, there is some potential to rehabilitate hydropower systems that were in place prior to the civil war. The current state of SHP does not reflect Somalia's historical development and use of hydropower. Though it has fallen into disrepair, the Fanoole Hydro-Electric Dam was completed in 1982 in partnership with China. The dam was designed to generate electricity for local communities in Jilil and Marerey, and to support an agricultural program focused on sugar cane and rice irrigation.[13] In their 2016 Intended Nationally Determined Contributions (INDC) report, the Government of Somalia announced plans to rehabilitate the dam's hydroelectric infrastructure at an estimated cost of US$ 28 million.[13] If completed, the refurbished dam would restore 4.6 MW of power and re-establish two standby generators with a capacity of 1,600 kW. This dam has the potential to reinvigorate the agricultural sector in the Middle and Lower Jubba Valley, but the project includes extensive repairs and rechannelling the path of the river that was diverted during the 1998 El Nino rainy season. Somalia's SHP potential is unknown and is based only on known planned projects (Figure 2).

Figure 2.
Small hydropower capacities 2019 in Somalia (MW)

Source: AfDB,[5] REEEP Policy Database[9]

Note: Somalia is a new country introduced in the *WSHPDR 2019*

Relative to Ethiopia's abundance of hydroelectric energy generation (nearly 2 GW), Somalia has a much more limited capacity. The country has an estimated economic potential capacity of 100 MW to 120 MW of total hydropower power, which is concentrated along the Shabelle and Juba rivers in the south.[5, 8] Historically, there were also plans to construct a Bardheere Dam upstream of the Fanoole Dam with a capacity of 493 MW, but the civil war effectively halted the project.[13] This reflects many of the challenges faced by Somalia in initiating SHP projects, namely the lack of financing from the Government and international donors, the current drought conditions affecting the Eastern Africa region and the high degree of terrorist activity conducted by Al Shabaab.

Renewable energy policy

As mentioned, charcoal currently represents the most cost effective and accessible energy source in Somalia. However, the proliferation of charcoal consumption and its export to international markets in the Middle East has resulted in widespread deforestation, environmental degradation and negative health outcomes. The rising cost of charcoal (which sits at approximately 50 per cent of household incomes) and the vast potential for solar and wind power generation has driven federal and regional governments to integrate renewable energy into their development plans and policies.[5]

Table 3.
Renewable energy potentials

Type	Energy Potential	Location/Region
Solar	200 kW/km²	Coastal South Central Somalia
Wind	30 – 45 GWh/ km2	Puntland and Somaliland
Hydropower	100-120 MW	Juba and Shabelle river region

Source: Federal Government of Somalia,[6] REEEP Policy Database[8]

Given the lack of any regulatory frameworks, renewable energy has been integrated into the larger discussion and legislative push toward formal energy policy in Somalia. The different regional governments have committed to the energy/ renewable energy policy objectives detailed in Table 4.

Table 4.
Energy policies

Source	*Policy*	*Objective*
Federal Govt. Somalia	2014-2015 Economic Recovery Plan	Incorporated provisions for renewable energy integration
	2017-2019 National Development Plan	Sustainable Energy Investment Policy and Energy Strategy provision
Somaliland Ministry of Energy and Mining	Somaliland Energy Policy 2010	Promotion of renewable energy technology, and reduction of taxes and duties on importing renewable equipment.
		Increase budget allocation to Ministries overseeing renewable energy activities.
		Infrastructure resources (i.e. transportation and communications) to help administrators implement and monitor renewable energy related activities.
		To develop and sustain efficient use of renewable energy resources as part of the energy mix, in ways that increase affordable access in urban and rural areas.[11]
Puntland	2014-2016 Puntland Government Plan	Identified renewable energy as one of four key priorities for the economy.[8]
		Target: 20 per cent increase in solar and wind energy generation and usage over a five-year period.

Source: Federal Government of Somalia,[7] REEEP Policy Database,[9] One Earth Future[8]

Barriers to small hydropower development

The key challenges that Somalia faces in developing SHP are as follows:

- Security concerns surrounding regional terrorist groups, such as Al Shabaab, and the potential for SHP infrastructure and energy grids to be targeted or attacked;
- Lack of field studies for SHP potential;
- Limited government capacity to administer and regulate the energy sector;
- Lack of a skilled workforce to design, build and maintain SHP and renewable energy infrastructure due to the prolonged conflict;
- Absence of an interconnected grid system with high enough capacity to support transmission and usage of electricity to both urban and rural populations;
- Aging equipment and poor infrastructure in thermal generation, which contributes to up to 50 per cent power loss;
- Scarcity of private sector financing for renewable energy projects and materials;
- Limited interconnection with regional power pools, particularly those in Ethiopia;
- International donor support needed for large-scale government projects, including rehabilitating SHP plants in poor condition and initiating a mini-grid system in key urban areas.

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South Sudan

1.1.11

Loboso Cosmas Manase Akwenya, South Sudan Electricity Corporation

Key facts

Population	12,323,419[1]
Area	644,330 km^2 [2]
Climate	South Sudan is located north of the equator. Its climate is tropical and hot throughout the year with seasonal rainfalls influenced by the annual shift of the intertropical convergence zone. The maximum temperature reaches 45 °C between February and April, and the minimum temperature of 10 °C is observed between December and January in the northern part of the country. South Sudan has two seasons – summer and winter. In summer, which starts in April and lasts until November, the weather is hot and humid with rains, whereas in winter, from December to March, it is hot and dry and sometimes windy.[3]
Topography	The landscape of South Sudan is primarily made up of tropical forests, swamps and grasslands. The terrain is plain in the north and centre and rises to the southern highlands. The Imatong mountains are located to the south-east and extend into Uganda. The highest point in these mountains is Mount Kinyeti at 3,187 metres above sea level. The lowest point in the country is the White Nile to the north at 350 metres.[5]
Rain pattern	In South Sudan, the wet season begins in April and ends around late November. Rainfall is heaviest in the upland areas of the south and reduces to the north. In most of the country, precipitation is between 800 and 1,100 mm per year, with minimum rainfall occurring in winter, when there is almost no rain, and the maximum being in the summer in the months of July and August.[3] The driest areas are the extreme south-east bordering Kenya and the far north-east bordering Sudan with annual precipitation below 700 mm.[3] In contrast, in the far south-west near the border with the Democratic Republic of the Congo the precipitation reaches 1,500 mm.[3]
Hydrology	South Sudan lies in the Nile basin, with 20 per cent of the basin lying in South Sudan. The Nile system within South Sudan comprises. • The White Nile system, upstream of the Sobat, originating on the Great Lakes plateau; • The Baro/ Sobat river system originating in the Ethiopian highlands; • The Bahr El Ghazal basin, an internal basin in the west of the country that also extends into Sudan. Both the Sobat and the Bahr el Ghazal are seasonal rivers, as opposed to the Nile, which is permanent. The White Nile enters the country from Uganda in the south and runs through the country towards Sudan in the north. The water of the Nile and its tributaries is absorbed into the largest swamp in the world, called the Sudd, covering an area of 320 km by 400 km and located in the central part of the country. The Sudd, also known as the Um Ruwaba basin, is the major ground water formation in South Sudan. It is made up of lakes, swamps, marshes and flood plains.[4]

Electricity sector overview

South Sudan became the newest African country after gaining its independence in 2011 as a result of a long civil war. The electricity sector in South Sudan is still undeveloped, and there has never been any electricity transmission backbone dating back to when it was one country with Sudan. Before the country gained independence, electricity supply was only limited to three urban areas: Juba, with an installed capacity of 5 MW; Wau, with an installed capacity of 2 MW; and Malakal, with an installed capacity of 2 MW from isolated mini-grids using small diesel generators.[6]

The energy needs in South Sudan are predominantly met by using biomass by burning charcoal and firewood. Over 90 per cent of the population use charcoal or wood as their primary fuel for cooking. South Sudan is yet to develop its electricity sector, and what exists now are isolated small grids serving the urban areas Juba, Malakal, Wau, Renk, Bor, Yambio, Rumbek, Yei, Maridi and Kapoeta. The source of generation in these areas is exclusively thermal from using diesel or heavy fuel oil (HFO) fired generators. The total installed capacity of these isolated small grids is 82.44 MW, whereas available capacity is 56.04 MW.[6]

For the last four years there has been no electricity generation at any of the isolated stations due to the economic crisis in the country. Most of the households and businesses in the urban areas that can afford it run individual generators as the utility is in blackout.

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

Source: South Sudan Electricity Corporation[6]

South Sudan is blessed with abundant natural resources, such as oil and natural gas. Oil is the main export commodity, contributing 80 per cent of the total income of the country.[1] Apart from oil and natural gas, the country has a high potential for renewable energy to generate electricity, including small to large hydropower, solar photovoltaic, wind, biomass, geothermal and waste-to-energy. These resources are yet to be developed to meet the energy demands of the country. After getting independence, the Government of South Sudan created a ministry to oversee the policies of the electricity sector, with the South Sudan Electricity Corporation as the operating arm. The Government identified energy as one of the pillars of accelerating economic growth of the country and ambitious plans were prepared to lay down the backbone of the electricity and energy sectors. But, only two years after gaining independence, the country was again plunged into a war due to political differences in the ruling party. Currently, the country remains in a state of political instability, which has made its economy one of the most ineffective in the world and has brought development of the electricity sector to a halt. Most of the South Sudanese sustain their living through subsistence agriculture and livestock keeping.

Although South Sudan is rich in natural resources, political stability and conducive environment must prevail in order to attract investors. At the moment, the country's economy is at its weakest point. The oil industry, on which it relied entirely for its exports, was interrupted by the war in 2013 where the country lost over half of its production. This led to a reduction in the nation's annual budget, making the operation of the isolated power systems difficult. South Sudan also has very rich agricultural land with many forests and one of the largest populations of pastoralists in the world. The electricity sector can be developed based on these resources when political stability is attained, especially in the rural areas. The South Sudanese electrification strategy prioritizes the use of the indigenous resources, namely oil and hydropower, to provide electric power for basic services and to meet the development needs of the country.

The Ministry of Energy and Dams is the sole institution mandated to formulate policies and oversees and acts as the regulator for the electricity sector. The South Sudan Electricity Corporation is the only government utility mandated to generate, transmit, distribute and sell electricity throughout the country. The Ministry of Energy and Dams is now laying a legal and policy framework and planning to achieve sustainable electricity in the short- and long-term. Currently, there are no private sector actors in the electricity market. Much as the draft South Sudan Electricity Policy allows for private-public partnerships in electricity generation, transmission and distribution, private sector actors are still reluctant to invest in the sector. The main constraints to the private actors' involvement are political and economic instability and the lack of a clear legal and regulatory framework.

South Sudan has no electricity grid and did not have one even before separating from Sudan. It is yet to develop an electricity grid backbone. Electricity was only available in few urban areas, supplied by diesel generators connected to the distribution networks at 11 kV, then stepped down to 415/240V for the household use.[12]

As the country has no infrastructure, the Government is focused on laying the foundation for future growth in the following areas:

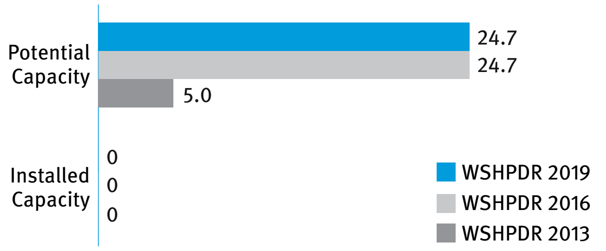
- A legal and regulatory framework to be enacted as soon as possible to include measures to promote grid and off-grid programmes, including partnerships with the private sector;
- Comprehensive, sector-wide capacity building programmes to be carried out to address the capacity constraints faced by sector institutions;
- Off-grid programmes to be expanded to cover all the states in the short term, with long-term planning and project preparation to be carried out for the least-cost programmes in generation, transmission and distribution. The development of renewable energy is in the Government programmes for the short-term energy solutions.

There are still no formulated policies with regards to electricity tariffs, and what is being used was inherited from Sudan. When the Electricity Regulator is in place, the policies for setting the tariffs are unlikely to be implemented. Due to the high rates of depreciation of the South Sudanese pound against the US dollar, the average electricity tariff for the year 2018 was adjusted to US$ 0.5 per kWh compared to US$ 0.15 per kWh in the neighbouring Uganda.[7,8]

Small hydropower sector overview

Although South Sudan as a country is rich in hydropower resources, it does not yet have any hydropower developed, be it small or a large. The country has no definition for small hydropower (SHP), as the policies for renewable energy have not yet been formulated.

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



Source: Government of South Sudan,[9] *WSHPDR 2013*,[10] *WSHPDR 2016* [11]

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

Although there are still no installed SHP capacities in South Sudan, government plans are underway to develop this sector. A few SHP sites have been identified and feasibility studies finalized, with development pending available financing. The sites are listed in Table 1.

Table 1.
Identified potential small hydropower sites in South Sudan

River	*Number of sites*	*Capacity (MW)*
Kinyeti River	4	3.5
Yei River	4	3.5
Sue River	5	13.5
Kaya River	3	4.2
Total	**16**	**24.7**

Source: Government of South Sudan[9]

There are many other SHP sites not yet identified or studied, hence significant investment is required to carry out feasibility studies of more potential sites. The challenges of financing remain a big obstacle, as the government is facing an economic crisis at the moment.

Renewable energy policy

Emerging from civil war, the country has no established laws and regulations for the renewable energy sector. However, if the country is to promote the use of renewable energy, the Government should focus on adopting comprehensive renewable energy legislation, establishing renewable energy strategies and action plans and developing a financial mechanism for the sector.

Barriers to small hydropower development

South Sudan is a country that has for many years experienced wars, leaving it with no infrastructure developed, hence there are many barriers to SHP development, including:

Regarding political instability:
- Relevant laws for the renewable energy are not enacted;
- Strategies for renewable energy are not in place;
- War has made access to sites for feasibility studies difficult;
- Displaced population.

Regarding economic performance:
- High rate of inflation does not attract investors;
- Lack of adequate banking to provide loans to investors;
- Lack of financial mechanisms for SHP projects.

Political and economic factors are currently the major determinants for SHP development in South Sudan.

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1.1.12 United Republic of Tanzania

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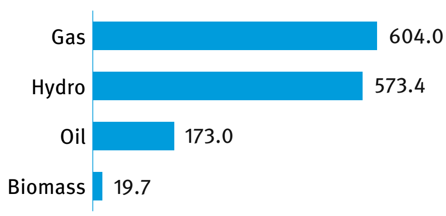
Key facts

Population	51,557,365[1]
Area	947,300 km^2
Climate	In Tanzania the climate is tropical. In coastal areas it is hot and humid, while the north-western highlands are cool and temperate. There are two rainy seasons: the short rains are generally from October to December, while the long rains last from March to June. The central plateau tends to be dry and arid throughout the year.[2]
Topography	Coastal areas are characterized by plains, which lead to a central plateau and highlands in the north and south. The highest point is Mount Kilimanjaro at 5,895 metres above sea level in the north-east of the country.[3]
Rain pattern	The rainfall pattern is subdivided into tropical on the cost, where it is hot and humid (rainy season March-May), and semi-temperate in the mountains, with short rains (Vuli) in November-December and long rain (Masika) in February-May. Average annual rainfall varies from 500 mm to more than 2,500 mm. The dry season lasts on average for five to six months. Rainfall patterns have recently become much more unpredictable with some regions receiving extremely low or extremely high rainfall per year.[4]
Hydrology	Tanzania is surrounded by water bodies covering 59,050 km^2 or approximately 6 per cent of the total area. Major water bodies include the Indian Ocean on the east coast, Lake Victoria in the north-west, Lake Tanganyika in the west and Lake Nyasa in the south. Rivers in Tanzania belong to nine water basins: Pangani River Basin, Rufiji River Basin, Lake Victoria, Wami-Ruvu, Lake Nyasa, Lake Rukwa, Lake Tanganyika, Internal Drainage and the Ruvuma and Southern river basins. Major rivers in Tanzania include the Rufiji River, Great Ruaha River, Kagera River, Ruvuma River, Wami River, Malagarasi River, Mara River and Pangani River.[3,5]

Electricity sector overview

As of 2016, the total installed capacity in the United Republic of Tanzania was 1,370.10 MW. The country's electricity sector was dominated mainly by the thermal power plants, with an installed capacity of 604 MW (44 per cent) from the natural gas-powered stations, 173 MW (13 per cent) from liquid fuel and 19.7 MW (1 per cent) from biomass. The installed capacity of hydropower plants stood at 573.4 MW (42 per cent).[6] The Government of Tanzania plans to accelerate industrial development and has the objective of expanding the power generation capacity up to 4,915 MW by 2020.[6]

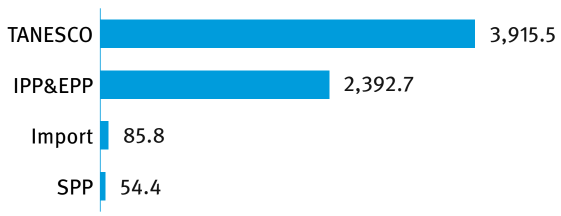
Figure 1.
Installed electricity capacity by source in Tanzania (MW)



Source: Ministry of Energy[6]

The country's electricity subsector is dominated by the grid network owned by the state-owned company Tanzania Electric Supply Company Limited (TANESCO). However, the 2009 Electricity Act opened the sector for private companies and ended the 40-year monopoly held by TANESCO. The penetration of independent power producers (IPPs) so far has been limited but steadily increasing.

Figure 2.
Electricity supply by producer in Tanzania (GWh)



Source: EWURA[7]

In 2016, TANESCO generated about 61 per cent of the total electricity supply in the country. IPPs and emergency power producers (EPPs) accounted for 37 per cent of electricity generation, small power producers (SPPs) for just 1 per cent and cross boarder imports for 1 per cent. Total electricity supply in 2016 amounted to 6,448 GWh (Figure 2).[7]

Despite the abundance of small hydropower (SHP) resources in most parts of the remote areas of Tanzania, the rural areas of the country remain virtually unelectrified. According to the Energy Access Situation Report, 2016, the electrification rate was relatively much higher in urban areas, at 65.3 per cent, than in rural areas, where it stood at 16.9 per cent.[8]

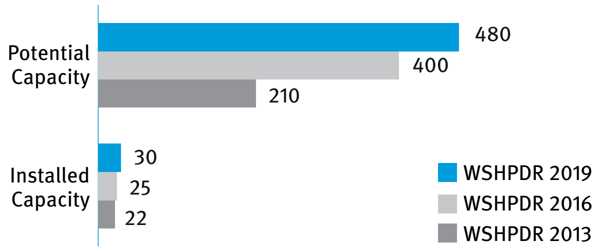
For many years the country's rural electrification efforts were focused on the grid extension, which has proved to be economically unsustainable and financially prohibitive. Decentralized renewable energy has been considered as an alternative to shift the country's focus from grid extension to rural electrification. The Rural Energy Act of 2005 established the Rural Energy Board, Rural Energy Fund and Rural Energy Agency, which are responsible for the promotion of improved access to modern energy in rural areas. Since the country's energy sector reform in 2005, there has been a considerable increase in electrification rates in urban and rural areas, which has been largely underpinned by the efforts of the Government in deploying renewable energy technologies, including hydropower.

Electricity tariffs for consumers are divided into groups depending on the use of electricity. The average electricity tariff for domestic consumers is 0.15 US$/kWh. A solid framework was established for the trade of electricity between producers and the regulation of TANESCO by the Energy and Water Utility Regulatory Authority (EWURA). For SHP projects below 10 MW, there are Standardized Power Purchase Agreements (SPPAs) and an established technology-specific feed-in tariff. For SHP projects, the tariff is also subdivided according to the installed capacity. The tariff is 0.155 US$/kWh and 0.085 US$/kWh for 100 kW and 10 MW installed capacities, respectively.[5,7]

Small hydropower sector overview

In Tanzania, SHP plants are defined as plants with an installed capacity up to than 10 MW. The current estimated installed capacity is at 30.363 MW, which includes isolated or unconnected plants. The total estimated potential is 480 MW, indicating that approximately 6 per cent has been developed.[6,13] Compared to the data from the *World Small Hydropower Development Report (WSHPDR) 2016*, both the installed and potential capacities have increased by 20 per cent (Figure 3). Potential capacity has been increasing due to new studies identifying new sites suitable for SHP development.

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



Source: *WSHPDR 2016*,[5] Ministry of Energy,[6] *WSHPDR 2013*,[10] AfDB[13]

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

For many years the SHP schemes have been mainly championed by the missionaries for the provision of power to community facilities, such as health centres, schools and vocational centres. As a result, most of the developed SHP projects are owned by private entities and are not connected to the national electricity grid. Five sites in the 300 kW–8,000 kW range are owned by TANESCO and others are owned by faith-based groups and private entities (Table 1).[9]

The current rural electrification approach is based on drawing energy from diverse sources, of which SHP is the major potential source. In the midst of the rising importance of harnessing SHP, the World Bank, through the Energy Sector Management Assistance Program (ESMAP), has funded a countrywide inventory of SHP potential resource mapping under the supervision of the Rural Energy Agency. It was completed in 2017 for the purpose of updating the directory of SHP resources of the country.[12] Table 2 summarizes 17 prioritized sites out of the more than 400 sites identified by the study.

Table 1.
Installed small hydropower plants in Tanzania

Site name	*District / region*	*Year installed*	*Installed capacity (kW)*	*Developer/ Owner*
NyumbayaMungu	Same/Kilimanjaro	—	8,000.0	TANESCO
Mwenga	Mufindi/Iringa	2010	4,000.0	Mufindi Tea Company
Tosamaganga	Iringa	1951	1,220.0	TANESCO
Kikuletwa	Moshi/Kilimanjaro	—	1,160.0	TANESCO
Mbangamao	Mbinga/Ruvuma	2015	1,000.0	Andoya Hydroelectric Power Company
Mbingu	Ifakara/Morogoro	2009	850.0	Mbingu Sisters Convent
Uwemba	Njombe	1971	800.0	Benedict Fathers

Site name	*District / region*	*Year installed*	*Installed capacity (kW)*	*Developer/ Owner*
Mbarari	Mbarari/Mbeya	1972	700.0	NAFCO/Government
Mngeta	Ifakara/Morogoro	—	600.0	Government parastatal
Uvinza Mine	Uvinza/Kigoma	—	600.0	Private
Chipole	Songea/Ruvuma		400.0	RC Mission
Mbalizi	Mbalizi/Mbeya	1958	350.0	TANESCO
Mawengi	Ludewa/Njombe	2013	300.0	RC Njombe diocese and village community
Lupa	Ifakara/Morogoro	—	200.0	Mission
Bulongwa	Makete/Njombe	—	180.0	Mission (Not Specified)
Mavanga	Ludewa/Njombe	2002	150.0	RC mission/Mavanga Village community
Matembwe	Njombe	1986	150.0	RC mission/CEFA/Matembwe Village
Lugarawa	Ludewa/Njombe	1979	140.0	RC Mission
Ndolela	Songea Rural/Ruvuma	—	100.0	Tea Estate
Kabanga	Kasulu/Kigoma	—	100.0	Mission
Ndolage	Mbinga/Ruvuma	—	100.0	Mission
Kitai	Songea/Ruvuma	1976	45.0	Prisons Dept/ Government
Kaengesa	Sumbawanga/Rukwa	1967	44.0	RC Mission
Ikonda	Makete/Njombe	1975	40.0	RC Mission
Nyangao	Nyangao/Lindi	—	38.8	Mission (not specified)
Peramiho	Songea Rural/Ruvuma	1962	34.6	Benedict Fathers
Rungwe	Tukuyu/Mbeya	1964	21.2	Moravian Mission
Matombo	Matombo/Morogoro	2013	20.0	Village community
Nyagao	Lindi	1974	15.8	RC Mission
Isoko	Tukuyu/Mbeya	1973	15.5	Moravian Mission
Ngaresero	Arusha	1982	15.0	M.H Leach
Ndanda	Lindi	—	14.4	Mission (not specified
Kinko	Lushoto/Tanga	2006	10.0	Village community
Sakare	Soni/Tanga	1948	6.3	Benedict Fathers
Tulila	Songea/Ruvuma	2016	5,000.0	Benedictine Sisters of St. Agnes, Chipole
Kiliflora	Arusha	2017	280.0	Kiliflora Company LTD
Salala/Ludilu	Makete/Ludewa	2017	68.0	Nishati Associate /Village Community
Iyovi	Kilosa/Morogoro	2015	950.0	Msolwa Stigmate Fathers & Brothers
Lilondo	Songea/Ruvuma	2015	40.0	Village Community
Igominyi	Njombe	—	10.0	Igominyi Community
Limage	Njombe	—	10.0	Limage Community
Total			**27,778.6**	

Source: *WSHPDR 2016*,[5] Michael,[9] Kassana et al.,[14] SHP Centre Tanzania[15]

Note: Not all operational SHP plants are shown in the table.

Table 2.
Small hydropower sites prioritized for development

Site name	*River*	*Connection*	*Capacity (kW)*
Kitogota Falls	Kitogota	Bukoba Minigrid	160
Muyovozi	Muyovozi	Kibondo Minigrid	3,990
Mgambazi	Mgambazi	Kigoma Minigrid	2,870
Kelolilo	Kelolilo	Ludewa Minigrid	400
Kigogo	Kigogo	Main grid	1,930
Mbagala	Mbagala	Masasi Minigrid	3,530
Luaita	Luaita	Mbiga Minigrid	200
Kitandazi II	Mbinga	Mbinga Minigrid	330
Mfizi II	Mfizi	Mpanda Minigrid	3,040
Momba I	Momba	Sumbawanga Minigrid	5,860
Lwazi	Lwazi	Sumbawanga Minigrid	2,100

Site name	*River*	*Connection*	*Capacity (kW)*
Chulu	Chulu	Sumbawanga Minigrid	2,240
Kalambo I	Kalambo	Sumbawanga Minigrid	840
Kalambo II	Kalambo	Sumbawanga Minigrid	850
Sumya	Sumya	Sumbawanga Minigrid	1,570
Muhuwezi	Muhuwezi	Tunduru Minigrid	2,680
Muyombezi	Muyombezi	Off-Grid	100
Total			**32,690**

Source: ESMAP[12]

Table 3.
List of small hydropower sites in various development stages

Name	*Developer*	*Potential capacity (kW)*	*Project status*
Uvinza hydropower project (Kigoma) – Malagarasi	Yet to be determined	8,000-24,000	Feasibility Level
Kilocha (Ruhudji) SHPP (Iringa)	Njombe Roman Catholic Church	10,000	Feasibility Level
Kitonga SHPP (Iringa)	Kitonga Electric Co	10,000	Feasibility Level
Momba hydro project (Mbozi	Mbozi DC & CAMS SKY AFRICA	10,000	Feasibility Level
Nakatuta SHPP (Songea Rural)	Yet to be determined	9,200	Feasibility Level
Kiwira – Malasusa falls (Rungwe)	Mkonge Energy Systems	8,000	Feasibility Level
Kikuletwa II (Hai)	Community Development Cooperation	8,000	Feasibility Level
Kitiwaka hydropower project (Ludewa)	Ludewa DC & CAMS SKY AFRICA	8,000	Feasibility Level
Nzovwe SHPP (Sumbawanga)	-	8,000	Feasibility Level
Kimani SHPP	Yet to be determined	7,000	Reconnaissance
Tulila small hydropower (Songea Rural)	Benedictine Sisters – Chipole	6,500	Commissioned
Saadani SHPP (Mufindi)	Fox Company Limited	5,900	Feasibility Level
Luswisi (ileje)	Kikundi cha MazingiraIleje Mashariki – CBO	3,200	Feasibility Level
Kwitanda hydropower project (Tunduru)	Kwitanda Community	3,000	Feasibility Level
Sunda Falls (Tunduru)	Tunduru DC & CAMS SKY AFRICA	3,000	Feasibility Level
Lingatunda (Mahanje – Songea Rural)	RC Parish Mahanje	3,000	Feasibility Level
Ilondo Hydropower Project (Mufindi)	Fox Company Limited	2,700	Feasibility Level
Mngazi hydropower (Morogoro)	TBA	2,100	Feasibility Level
Nyakifunga Falls (Njombe)	Yet to be determined	2,050	Feasibility Level
Isigula SHPP (Mkiu – Mlangali) – Ludewa	Kisangani Group	2,000	Feasibility Level
Mtambo SHPP (Mpanda)	Electromechanical Systems	2,000	Feasibility Level
Lwega Small Hydropower Project (Mpanda)	MOFAJUS Investments	2,000	Feasibility Level
Pinyinyi SHPP (Ngorongoro)		1,900	Feasibility Level
Luiche hydropower project (Sumbawanga)	Ulaya Hydro & Windmill Technology	1,610	Feasibility Level
Balali SHPP (Njombe)	Yet to be determined	1,500	Reconnaissance
Darakuta SHPP (Babati)	Darakuta Farm Ltd	1,350	Detailed Design
Luganga (Iringa)	Makete Power Services	1,200	Feasibility Level
Nkwiro SHPP (Sumbawanga)	Ulaya Hydro & Windmill Technology	1,165	Feasibility Level
Ndugu hydropower Project	LM Investments	900	Feasibility Level
Nyalawa hydro project (Mufindi)	Yet to be determined	835	Feasibility Level
Lupali SHP-MG (Njombe)	Benedictine Sisters – Imiliwaha	640	Under construction
Macheke Falls (Mlangali) – Ludewa	MLADEA/LUDEA	420	Feasibility Level
Luaita hydro Project (Mbinga)	Yet to be determined	400	Feasibility Level

Name	*Developer*	*Potential capacity (kW)*	*Project status*
Mtombozi SHPP (Morogoro)	Yet to be determined	380	Feasibility Level
Makurukuru (Lumeme River) SHPP	Andoya Hydro Electric Company Ltd	350	Feasibility Level
Mugali River – Maruruma (Mufindi)	Masana Village	300	Reconnaissance
Kingerikiti (Lumeme River – Mbinga) SHPP	Andoya Hydro Electric Company Ltd	300	Feasibility Level
Simike Small Hydropower Project (Rungwe)	RETDCO	300	Feasibility Level
Mwoga SHPP (Kigoma)	Kasulu District Council	300	Feasibility Level
Nole (Njombe)	RC Parish Nole	300	Feasibility Level
Mpando SHPP (Njombe	CHAMAI	220	Feasibility Level
Ilundo hydropower project (Rungwe)	Ilundo Community	200	Feasibility Level
Malindindo (Mbinga)	Malindindo Community	200	Feasibility Level
Ijangala SHPP (Makete)	TandalaDiaconical Centre	200	Detailed Design
Mmangaminhydroplant (Morogoro)	Tawa Ward Community	50	Feasibility Level
Wangama (Njombe)	Wangama Community	48	Feasibility Level
Kindimba SHPP (Mbinga)	Mbinga Community (CBO)	40	Feasibility Level
Magoda (Njombe)	Magoda Community	25	Feasibility Level
Kilondo Small Hydropower Project	Kilondo Investmeny/ Village Community	50	Under construction

Source: *WSHPDR 2016*,[5] SHP Centre Tanzania[15]

Renewable energy policy

No policy on renewable energy has been developed in Tanzania so far. However, the Ministry of Energy and Minerals is currently reviewing the National Energy Policy (2003), which states the national commitment to sustainable energy production and use, including the objective to enhance the development and utilization of indigenous and renewable energy sources.

As part of the Government's agenda to make the renewable sources an integral part of the rural energy and power sector development strategies, the following policies were issued:

- The rural electrification policy statement 2005 indicates that all lower-cost technical options should be considered, including renewable energy;
- The Rural Energy Act (2005) established the Rural Energy Board, Rural Energy Fund and Rural Energy Agency, with the main tasks of promoting access to modern energy services and allocating performance-based subsidies for rural energy including renewable energy systems;
- The Energy and Water Utility Regulatory Authority (EWURA) Act (2001) mandates the regulator to set tariffs, affecting the renewable energy IPPs.[5]

Furthermore, in order to ensure adequate supply, the Electricity Act (2008) created procedures for providing electricity from different sources. EWURA designed a model for Standardized Small Power Purchase Agreement/Tariff (SPPA/T) for private producers with project capacities below 10 MW. In 2015, the framework was reviewed introducing two approaches depending on the technology, with feed-in tariffs being applied for SHP and biomass and a bidding approach being applied for solar and wind power.[5,11]

Further environmental and land policy and legislation influencing renewable energy development in Tanzania include: the Environmental Management Act of 2004, the National Land Policy of 1997 and the National Environmental Policy of 1997.[13]

Barriers to small hydropower development

It has been found that, despite the need for SHP schemes and the availability of potential SHP sites in Tanzania, most of the sites are not yet developed due to a number of reasons, including:

- Lack of financial sustainability for project developers, such as non-governmental organizations, community-based organizations and municipals;
- Lack of local skills and know-how and lack of self-initiatives for SHP development, hence the need for technical assistance in the planning, development and implementation of SHP projects;
- Lack and low level of local technology for pico-, micro- and SHP to harness the existing hydropower potential. Therefore, networking, knowledge sharing and information dissemination through forums and conferences are necessary;
- Lack of infrastructure in the design, manufacture, installation and operation of turbines;
- Characteristics of rural hydropower electricity market: the majority of the rural population in Tanzania are poverty-prone, with the majority not being able to afford the initial connection costs and monthly bills;

- Rural electrification policy: without appropriate policy and its implementation strategies, rural energy development follows an ad hoc path, as it does today, with little recourse to the national energy plan;
- Insufficient information about potential sites;
- Inadequate SHP awareness, incentives and motivation. [5]

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1.1.13 Uganda

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Key facts

Population	37,700,000 [1]
Area	241,559 km^2 [2]
Climate	Uganda has a tropical climate that varies from rainforest/monsoon in the south-east to drier, hotter savannah in the north. The mean annual temperature is about 26°C, with maximum temperatures ranging between 18 °C and 31 °C and minimum temperatures ranging between 15 °C and 23 °C. Temperatures are generally lower in the south-western highlands and higher in the north, with semi-arid conditions experienced in the north-east of the country.[2,3]
Topography	Uganda mostly consists of a plateau ranging in height from 800 metres to 2,000 metres and is rimmed by mountains. In the Rwenzori Mountains, stretching along the western border, the Margherita Peak is the highest point at 5,111 metres, while on the eastern border Mount Elgon rises to 4,324 metres. The point of lowest altitude is 620 metres on the Albert Nile.[4,5]
Rain pattern	Rainfall is well distributed, except in the north-east of the country where semi-arid conditions are experienced. The wet season lasts from March to May, and there are lighter rains in November and December, while the dry seasons are from December to February and from June to August. Annual precipitation ranges from 500 mm to 2,500 mm and relative humidity is in the range of 70 to 100 per cent.[2,3]
Hydrology	Uganda lies almost entirely within the drainage basin of the River Nile. The south-east of the country is dominated by Lake Victoria that extends into neighbouring Kenya and Tanzania and is the source of the River Nile. The White Nile flows north from Lake Victoria, through Lake Kyoga in Central Uganda and westward into Lake Albert on the border with the Democratic Republic of the Congo. The Albert Nile then continues northward into South Sudan. Other major water features are Lake George and Lake Edward which, along with Lake Albert, lie in the Western arm of the East African Rift Valley along the border with the Democratic Republic of the Congo.[3,5]

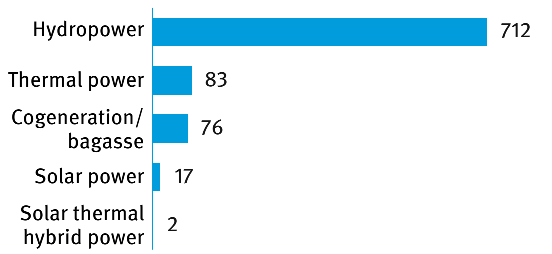
Electricity sector overview

Uganda has an abundance of natural energy resources, both renewable and non-renewable, including hydropower, biomass, solar, geothermal, peat and fossil fuels. The country's estimated energy resource potential stands at 2,000 MW of hydropower, 450 MW of geothermal, 1,650 MW of biomass cogeneration, 460 million tons of biomass standing stock with a sustainable annual yield of 50 million tons, an average of 5.1 kWh/m^2 of solar energy and about 250 Mtoe of peat (800 MW). Resources of petroleum are estimated at 6.5 billion barrels (1.4 billion barrels are recoverable). The overall renewable energy power generation potential is estimated to be 5,300 MW.[8]

As of April 2018, Uganda had about 943 MW of installed capacity, including 712 MW of hydropower, 136 MW of thermal power, 76 MW of cogeneration/bagasse, 17 MW of solar power and 2 MW of solar thermal hybrid power. However, only approximately 890 MW of this was licensed for generation (53 MW of thermal generation was unlicensed/decommissioned in 2017).[6,32] Figure 1 shows the energy mix of Uganda as of April 2018 based on licensed capacity.

In 2017, electricity generation in Uganda totalled 3,874 GWh, with hydropower accounting for approximately 89 per cent of total generation, thermal power for 6 per cent, bagasse for 4 per cent, solar power for 1 per cent and hybrid (solar/thermal) for 0.05 per cent (Figure 2).[6,32]

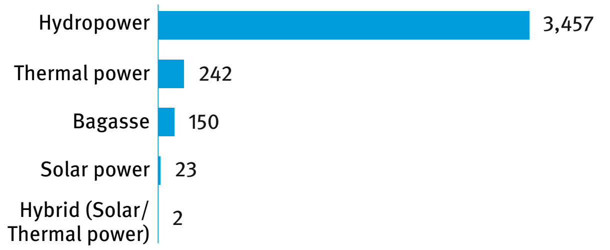
Figure 1.
Installed electricity capacity by source in Uganda (MW)



Source: ERA[6,32]

Biomass is the major source of energy in Uganda, accounting for 93 per cent of primary energy consumption. Fossil fuel combustion accounts for 6 per cent of energy demand and electricity accounts for the remaining 1 per cent.[7,8] Only about 15 per cent of the population has access to electricity, and in rural areas access is only at 7 per cent.[8,9] Uganda has one of the lowest levels of per capita electricity consumption in the world with 215 kWh per capita per year, relative to the Sub-Saharan Africa average of 552 kWh per capita and the world average of 2,975 kWh per capita.[8] The demand for electricity has been growing at a rate of 10 per cent per annum. In anticipation of growing demand, the Government has commissioned various hydropower projects, including the 600 MW Karuma hydropower project and the 183 MW Isimba Falls hydropower project.[8,9]

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



Source: ERA[6,32]

There are about 1,500 km of transmission lines (above 33 kV) traversing the country and the Government intends to double this. The existing transmission lines are to be upgraded and a 220 kV "ring" is to be developed in conjunction with Kenya and Tanzania so as to have a more robust regional electricity grid.[9]

The electricity sector in Uganda is run under a liberalized regime that followed the unbundling of the previous vertically integrated monopoly, the Uganda Electricity Board (UEB). Three companies were formed as a result: the Uganda Electricity Generation Company Limited (UEGCL) managing electricity generation, the Uganda Electricity Transmission Company Limited (UETCL) managing electricity transmission and the Uganda Electricity Distribution Company Limited (UEDCL) managing electricity distribution. These three companies are licensed and regulated by the Electricity Regulatory Authority (ERA).[11] The ERA is mandated to issue licences, regulate the operations of all electricity operators, including independent power producers (IPPs) and private distribution companies, and establish the tariff structure.[11]

Other key players in the energy sector are the Ministry of Energy and Mineral Development (MEMD) and the Rural Electrification Agency (REA). The MEMD provides policy guidance, creates an enabling environment to attract investment in the energy sector, acquires data on the country's resource potential and regulates activities of private companies in the sector.[12] The REA was established to facilitate acceleration in rural electrification. One of its key objectives is to promote equitable rural electrification access with special regard to marginalized communities. Its vision is to achieve universal electricity access by 2035.[13]

For grid-connected consumers, electricity prices are set at three interfaces: between generation and transmission; between transmission and distribution; and between distribution and end-users. In Uganda, UETCL acts as the single buyer of electricity. Electricity prices between UETCL and power generation companies are negotiated in the form of a power purchase agreement subject to approval by the ERA. UETCL then sells power to distribution companies at a bulk supply tariff (BST) reflective of the power purchase and transmission costs. The distribution companies then sell electricity to the end-users following an ERA-approved tariff schedule.

End-user electricity tariffs are determined following an automatic adjustment mechanism introduced by the ERA in 2012. The computation takes into account the exchange rate variation (Uganda Shilling versus US Dollar), fluctuations in oil prices on the international market, and local inflation levels. For certain categories of consumers, there is further tariff differentiation according to the time of use.[29] The single largest electricity distribution concessionaire in Uganda is Umeme Limited that is regulated by the ERA. The approved base electricity end-user tariffs for 2018 represented a weighted average increase of 3.3 per cent relative to the tariffs of the fourth quarter of 2017 (Table 1).[14]

Table 1.
Approved base electricity tariffs and applicable end-user tariffs for the period January to March 2018

Type of consumption	*Energy charge UGX (US$)/kWh*			
Domestic consumers Low voltage single phase supplied at 240 V				
Lifeline charge applicable for the first 15 units in a month	150.0 (0.041)			
Energy above 15 units	718.9 (0.195)			
	Average	*Peak*	*Shoulder*	*Off-peak*
Commercial consumers Consumers metered at low voltage three phase with load not exceeding 100 A and supplied at 415 V	648.3 (0.176)	839.6 (0.227)	646.3 (0.175)	401.4 (0.109)
Medium industrial consumers Medium industrial users taking power at low voltage 415 V, with maximum demand of up to 500 kVA	592.5 (0.161)	766.2 (0.208)	589.8 (0.160)	366.1 (0.099)
Large industrial c onsumers High voltage 11,000 V or 33,000 V, with maximum demand exceeding 500 kVA but up to 1,500 kVA	375.5 (0.102)	497.1 (0.135)	382.6 (0.104)	247.7 (0.067)
Extra-large *industrial consumers* High voltage 11,000 V or 33,000 V, with maximum demand exceeding 1,500kVA and dealing in manufacturing	371.1 (0.101)	491.8 (0.133)	378.5 (0.103)	246.5 (0.067)

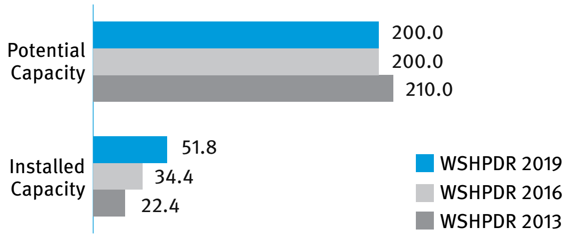
Source: ERA[14]

Small hydropower sector overview

In Uganda, small hydropower (SHP) is generally defined as hydropower plants with generation capacity of up to 20 MW.[18]

The total installed capacity of SHP plants of up to 20 MW in operation in Uganda is 82.8 MW (Table 2), whereas the potential is estimated at approximately 258 MW, indicating that approximately 32 per cent of potential capacity of SHP of up to 20 MW has been developed.[6,19,21,22] The installed capacity of SHP plants of up to 10 MW is 51.8 MW and potential capacity is approximately 200 MW, indicating that 26 per cent of the potential capacity of SHP of up to 10 MW has been developed.[6,19,21,22] Compared to the *World Small Hydropower Development (WSHPDR) 2016*, the potential of SHP plants of up to 10 MW has remained unchanged, whereas the installed capacity has increased by 51 per cent as a result of the commissioning of four new plants (Ishasha, Rwimi, Siti 1 and Kisilzi Hospital power plant) (Figure 3).

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



Source: *WSHPDR 2016*,[5] ERA,[6] ERA,[19] ERA,[21] KFW & Multiconsult,[22] *WSHPDR 2013* [31]

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

Table 2.
Small hydropower plants in operation (up to 20 MW)

Site	*District*	*Installed capacity (MW)*	*Operator*
Mpanga	Kamwenge	18	Africa EMS Mpanga Ltd.
Bugoye	Kasese	13	Bugoye Hydro Ltd.
Mobuku 3	Kasese	10	Kasese Cobalt Company Ltd.
Mobuku 1	Kasese	5.4	Kilembe Mines Ltd.
Buseruka	Hoima	9.0	Hydromax Ltd.
Ishasha	Kanungu	6.6	Eco Power Uganda Limited.
Muvumbe	Kabale	6.5	Muvumbe Hydro (U) Ltd
Rwimi	Kasese	5.5	Rwimi EP Company Limited
Siti 1	Bukwo	5.0	Elgon Hydro Siti (PVT) Limited
Nyagak	Nebbi	3.5	WENRECo.
Kisiizi Hospital Power	Rukungiri	0.3	Kisiizi Hospital Power Ltd
Total		**82.8**	

Source: ERA,[6] ERA,[19] KFW & Multiconsult,[22]

Table 3.
Planned small hydropower projects (up to 20 MW)

Developer	*Project Name*	*District*	*Capacity (MW)*
Elgon Hydro Siti (Pvt) Limited	Siti II SHP	Bukwo	16
Kikagati Power Company Limited	Kikagati HPP Project	Isingiro	16
TYAX Holdings incorporated Limited	Nyamagasani I	Kasese	15
PA Technical Services	Nkusi SHP	Kibaale/Hoima	9.6
South Asia Energy Management Systems LLC	Nyamwamba hydro Power Project	Kasese	9.2
C&G Andijes Uganda Ltd	Bukwa HPP	Bukwa	9
Ngoromwo Small Hydro Ltd	Ngoromwo HPP	Atari	8
Ziba Limited	Kyambura	Rubirizi	7.6
Eco Clean Power	Sironko HPP	Sironko	7
Jacobsen Elektro AS	Nengo bridge	Rukungiri	6.7
Keere Power Company Ltd	Keere Small HPP	Kapchorwa	6.3
Sindila Power Company Uganda Limited	Ndugutu HPP	Bundibugyo	5.9
Lubilia Kawembe Hydro Limited	Lubilia SHP	Kasese	5.4
Muvumbe Hydro (U) Limited	Nyakizumba Hydro Power plant	Kabale	5.4
TYAX Holdings incorporated Limited	Nyamagasani II	Kasese	5
Sindila Power Company Uganda Limited	Sindila SHP	Bundibugyo	5
UEGCL	Nyagak III	Zombo	4.4
PA Technical Services	Nyabuhuka-Mujumbi HPP	Kabarole	3.4
Network Civil Engineering Contractors Ltd	Nyabuhuka-Mujunju HPP	Kabarole	3.2
Mt Elgon Hydropower Limited	Muyembe-sirimityo	Sironko	3.1
Mahoma Uganda Limited	Mahoma HPP	Kabarole	3
Elemental Energy Limited	Nyamabuye	Kisoro	2.2

Developer	*Project Name*	*District*	*Capacity (MW)*
Cresta Hydropower Ltd	Cresta Mini Hydro power	Rubirizi	2
Flow Power-1	Pachwa HPP	Kibale	1.3
Total			**169.5**

Source: ERA,[6] ERA,[19] ERA,[21] KFW & Multiconsult[22]

There are many unexploited potential SHP sites in Uganda, which could potentially supply electricity to areas not covered by the national grid. The cost per unit of electricity from isolated SHP plants (mini-grids) may be higher than that from the national grid, but could sustainably contribute to poverty reduction in households in isolated areas.[19] Table 4 outlines SHP sites that are available for development.

Table 4.
Small hydropower sites available for development

Site	*District*	*Estimated Capacity (MW)*	*Remarks*
Ela	Arua	1.5	No Studies
Ririma	Kapchorwa	1.5	No Studies
Rwigo	Bundibugyo	0.48	No Studies
Nyarwodo	Nebbi	0.4	No Studies
Tokwe	Bundibugyo	0.4	Preliminary technical studies carried out under AERDP by MEMD
Agoi	Arua	0.35	No Studies
Kitumba	Kabale	0.2	No Studies
Amua	Moyo	0.18	No Studies
Ngiti	Bundibugyo	0.15	Preliminary technical studies carried out under AERDP by MEMD
Manafwa	Mbale	0.15	Preliminary technical studies carried out under AERDP by MEMD
Leya	Moyo	0.12	No Studies
Nyakibale	Rukungiri	0.1	No Studies
Miria Adua	Arua	0.1	No Studies
Total		**5.63**	

Source: ERA[19]

A generation licence may be granted to a developer following the submission of an application to the ERA, which processes the licence application within a maximum of 180 days. The process involves the publication of notices in the National Gazette and national newspaper to solicit objections to the project if any.[20]

There is a financial gap in the development of renewable energy sources in Uganda, however, as the existing renewable energy developments have been financed through various mechanisms including the Government, IPPs, development partners and public-private partnerships. The key sources of funding among these are the Global Energy Transfer Feed-in-Tariff (GET FIT) Programme and the support from Power Africa.

The main objective of the GET FIT Programme is "to assist East African nations in pursuing a climate resilient low-carbon development path".[19] One of the instruments of the GET FIT Programme is the GET FIT Premium Payment Mechanism (GFPPM). Small-scale renewable energy projects selected through a competitive bidding process apply for premium payments. These premium payments constitute an "incentive grant designed to enhance the financial viability of the selected projects and are payable to the project developers in addition to the relevant REFIT tariffs determined by the Electricity Regulatory Authority (ERA)".[23] Through the GET FIT Programme, a total of 158 MW of renewable energy is to be added to the national grid from a total of 17 projects utilizing various renewable energy technologies, including SHP, solar PV and bagasse.[22]

Power Africa is an initiative of various development partners that aims to "increase electricity access in sub-Saharan Africa by adding more than 30,000 MW of cleaner, more efficient electricity generation capacity and 60 million new home and business connections". It provides various resources to advance key projects on the grid and also supports off-grid and mini-grid projects.[9]

Renewable energy policy

The vison of the Government of Uganda is to make modern renewable energy a substantial part of the national energy. The Renewable Energy Policy (REP) of Uganda in 2007 stated the goal to increase the use of modern renewable energy as well as the introduction of FITs, standardization of Power Purchase Agreements, the obligation of fossil fuel companies to mix products with biofuels up to 20 per cent and tax incentives on renewable energy.[24]

The renewable energy institutional framework of Uganda comprises the following stakeholders:

- MEMD has the overall responsibility for the REP and oversees and coordinates its implementation with other stakeholders;
- The ERA sets tariffs, issues generation licences and maintains the REFIT;
- UETCL is the system operator and single buyer; generation companies agree on a power purchase agreement with UETCL;
- Renewable energy generation companies (subject to fulfilment of relevant conditions);
- Distribution licence holders.[5,24]

REFITs were introduced under the Renewable Energy Policy to promote a greater private sector engagement in power generation from renewable energy sources. The REFIT applies to systems of prescribed priority technologies (SHP, geothermal, bagasse, landfill gas, biogas, biomass, wind and solar) of installed capacity in the range of 0.5-20 MW, as defined by the Electricity Act, 1999. In addition, to qualify for the REFIT, the projects must be connected to the national grid. Plants including additional capacity resulting from the project modernization, repowering and expansion of existing sites, but excluding existing generation capacity, also qualify for the REFIT.[5,17,27] The REFITs for 2016-2018 are shown in Table 5.

Table 5.
REFIT Phase 3 tariffs, operation & maintenance (O&M) percentage, capacity limits and payment period

Technology	*Tariff US$/ kWh*	*O&M percentage*	*Cumulative capacity limits (MW)*			*Payment period (Years)*
			2016	*2017*	*2018*	
Hydropower (>10 MW and ≤20 MW)	0.094	10.96%	30	60	80	20
Hydropower (>5 MW and ≤10 MW)	Linear tariff*	10.49%	20	40	50	20
Hydropower (>500 kW and ≤5 MW)	0.107	10.49%	10	20	30	20
Bagasse	0.088	29.78%	30	50	60	20
Wind power	0.122	10.71%	25	50	75	20

Source: ERA[18]

Note: *Computed as a regressive allocation of costs with increase in plant size.

For technologies that have not yet been tested on the national grid (biogas, biomass and landfill gas), the REFIT rates are not fixed, but a ceiling price with maximum return on equity has been set so as to allow for bilateral negotiations while the regulator assesses each project on its individual merit.

Barriers to small hydropower development

According to the Fieldstone Africa Renewables Index, Uganda ranks second (after Morocco) among the "big five" countries on the African continent with the most compelling premise for investment in renewable energy.[25] The enabling regulatory environment, coupled with increased electrification and superior solar and hydropower resources, has resulted in notable progress for large and small generation projects in the country.[26] These plaudits notwithstanding, the electricity sector in Uganda still faces some of the challenges that may be classed as institutional, financial and political barriers.

The barriers to SHP development include the following:

- There is an infrastructure gap in the generation, transmission and distribution of electricity, such that the growing demand is not being met by the existing infrastructure. Distribution losses also remain quite high and there is need for further investment to extend the grid to unserved areas;
- There is a gap in financing of the power sector, which will not be bridged by the public sector financing alone, and a need for more private sector investment;
- High upfront costs and limited access to early-stage support and equity investment present another limitation, as interest rates from commercial lenders are quite high due to the perceived high risks of the investment;
- There is a perception of high risk of default on payment by the single off-taker;
- The land acquisition process is bureaucratic, complex and slow and affects the overall project costs and the construction of transmission line infrastructure required for the evacuation of power from power plants;
- There is a need for capacity building within the government institutions, particularly as relates to planning, design and construction of hydropower plants.[5,22,24,27,28]

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1.1.14 Zambia

Mundia Simainga, Martin Sinjala, Brenda Chizinga, Reynolds Mukuka, ZESCO LTD.

Key facts

Population	16,409,225[1]
Area	752,612 km^2[2]
Climate	Zambia has three seasons: cool and dry from May to August; hot and dry from September to November; and warm and wet from December to April. In the warm and wet season, frequent heavy showers and thunderstorms occur. Average temperatures are moderated by the height of the plateau. Maximum temperatures vary from 15 °C to 27 °C in the cool season, with morning and evening temperatures as low as 6 °C to 10 °C, and occasional frost on calm nights in valleys and hollows that are sheltered from the wind. During the hot season, maximum temperatures range from 27 °C to 35 °C.
Topography	The country is located on the great plateau of Central Africa at an average altitude of 1,200 metres and rises to a higher plateau in the east. The country has three main topographical features: mountains, with an altitude of at least 1,500 metres; a plateau, with an altitude ranging from 900 to 1,500 metres; and lowlands, with an altitude of between 400 and 900 metres.[4]
Rain pattern	Zambia receives moderate rainfall ranging from an annual average of approximately 600 mm in the south of the country to over 1,400 mm per year in the north. The country's annual average rainfall is 1,000 mm. The rainfall pattern over the whole country is similar between November and March, but the amount of rain varies considerably. In the north of the country, rainfall is 1,250 mm or more a year, decreasing southwards to Lusaka where it is about 750 mm annually. South of Lusaka, rainfall is dictated more by the east and south east trade winds. Rainfall in this area is between 500 and 750 mm.[5]
Hydrology	The country has five main rivers: the Zambezi, Kafue, Luangwa, Luapula and Chambeshi. The five main river basins incorporate the several small river basins at which small hydropower potential is vast. The country's major lakes are Tanganyika, Mweru, Mweru Wa Ntipa, Bangweulu, and the man-made lakes include Kariba and Itezhi-tezhi.[3] Large hydropower plants are mainly located in the lower areas of the above catchments while the small hydropower potential is mainly in the upper areas of said catchment areas.[6]

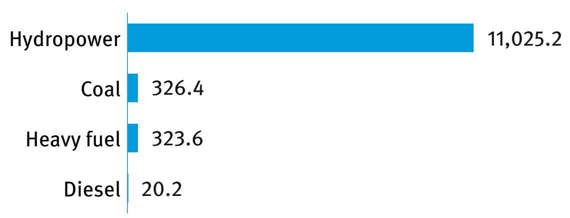
Electricity sector overview

Zambia's economy is primarily driven by mining, agriculture, construction, transport and communication. In recent years, the economic performance of the country has been positive, with the growth rate of real gross domestic product (GDP) averaging at 6.9 per cent. However, in 2015, Zambia was hit both by a decrease in copper prices and by domestic pressures, including a poor harvest after an El-Nino induced drought and a power crisis. This led to the economy tumbling to its lowest since 1998, however, growth is forecast to increase to 4.5 per cent in 2018 and 4.7 per cent in 2019.[7] The country's vision is to become a prosperous middle-income country by 2030 (Vision 2030) via enhanced private sector participation.[8]

Zambia's energy sources include electricity, petroleum, coal, biomass, and renewable energy, with petroleum being wholly imported to the country. Before 2018, the demand for electricity has been growing at an average rate of about 3 per cent per annum. This is mainly due to the increased economic activity in the country especially in the agriculture, manufacturing and mining sectors.[9] As of the end of 2016, the Zambian electricity system was mainly sustained by electricity from hydroelectric power generation stations.

Figure 1 shows the electricity generation by source in Zambia for 2016, hydropower contributes 94.3 per cent to the energy mix, with coal and heavy fuel contributing 2.8 per cent each and diesel contributing 0.2 per cent.

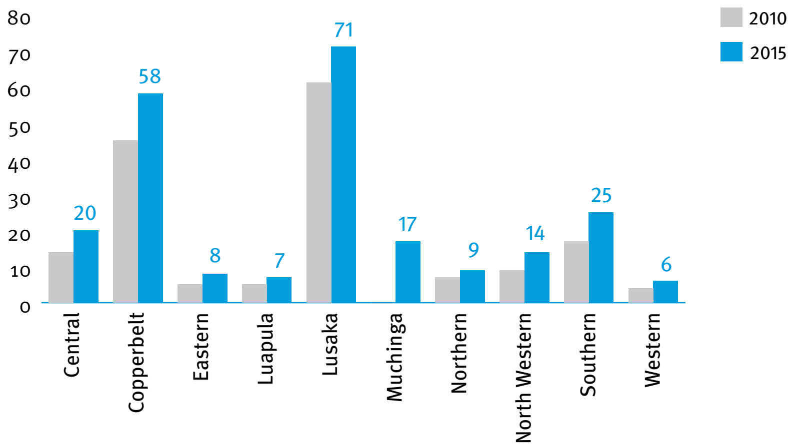
Figure 1.
Annual electricity generation by source in Zambia (GWh)



Source: Energy Regulation Board[9]

Zambia has four main hydropower stations situated in the southern part of the country. These are Kafue Gorge power station, with an installed capacity of 990 MW; Kariba North Bank Power station, with 720 MW; Victoria Falls Power

Figure 2.
Households connected to electricity by province for 2010 and 2015 (%)



Source: CSO[1]

station, with an installed capacity of 108 MW; and the newly commissioned Itezhi-Tezhi Power Station, with an installed capacity of 120 MW. These major stations are run by ZESCO Limited (ZESCO), a state-owned vertically integrated electric company. The country also had operational small hydropower (SHP) plants with a combined installed capacity of 89.8 MW owned by ZESCO and other independent power producers (IPPs).[9] The total national installed capacity in 2016 was 2,827 MW, as shown in Table 1.[9]

Table 1.
Installed electricity capacity in Zambia

Power Station	*Type*	*Capacity (MW)*	*Generation (GWh)*
KGPS	Hydropower	990.0	5,853
KNBPS	Hydropower	720.0	2,964
KNBEPS	Hydropower	360.0	672
Victoria falls	Hydropower	108.0	754
Itezhi-Tezhi	Hydropower	120.0	536.7
Small Hydro-power ZESCO	Hydropower	33.8	121.5
Mulungushi & Lunsefwa	Hydropower	56.0	121.9
Micro Hydro-power (Total)	Hydropower	0.9	2.1
Diesel Stations (Total)	Diesel	88.6	20.2
Mamba Power Plant	Coal	300.0	326.4
Ndola Energy	Heavy Fuel	50.0	323.6
Total		**2,827.3**	**11,695.4**

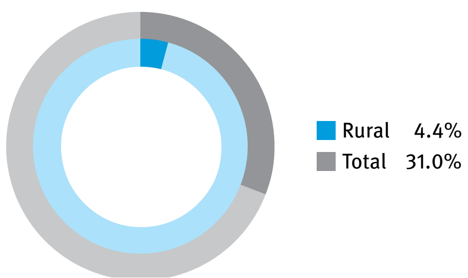
Source: Energy Regulation Board[9]

The demand for renewable energy has also seen significant growth in recent years as the market explored alternative sources of energy, with renewable energy proving to be a viable alternative. In 2016, the development of a regulatory framework for renewable energy was completed by the Energy Regulation Board of Zambia. The Renewable Energy Regulatory Framework (RERF) was developed in line with the National Energy Policy (2008), relevant legislation, the Biofuels Regulatory Framework, the Regulatory Framework for Off-Grid Systems and the Renewable Energy Feed-In Tariff (REFiT) Strategy. These documents individually strive to facilitate the implementation and diversification of the energy sector in order to promote renewable energy technologies and improve access to modern forms of energy.[9]

The electricity industry in Zambia is governed by the Electricity Act of 1995 and the Electricity Amendment Act of 2003. The electricity industry was liberalized in 1995 in order to attract investment in power generation, transmission and distribution. Private sector players that provide services include Copperbelt Energy Corporation (CEC), Lunsemfwa Hydro Power Company, Maamba Collieries Ltd and Zengamina.

Zambia is divided into 10 provinces.[3] Figure 2 shows a comparison of access to electricity for 2010 and 2015 in these 10 provinces. Only the Copperbelt and Lusaka provinces have access above 50 per cent, and in many other provinces only 10 per cent or less have access to electricity.[1]

Figure 3.
Electrification rate in Zambia (%)



Source: CSO[8]

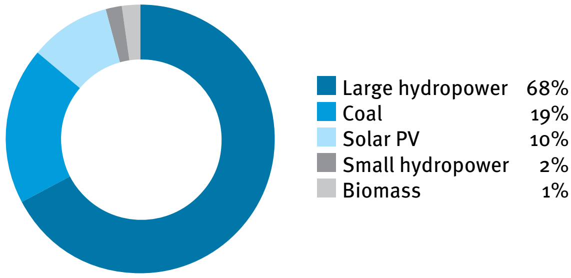
At the national level in 2015, 31 per cent of the households were stated as being connected to electricity. About 4.4 per cent of the households in rural areas had connection to electricity. In urban areas, 67.3 per cent of households had connection to electricity.[8] In 1994, the Government of Zambia established the Rural Electrification Fund (REF) by committing the sales tax to electricity, and has been trying to increase the electrification rate in rural areas by executing projects funded by REF. At that time, the household electrification rate was approximately 20 per cent countrywide, and only 2—3 per cent in rural areas.[13] As a mid-term target, achieving 35 per cent of household electrification rate (50 per cent in urban areas and 15 per cent in rural areas) by 2010 was set in the 2002 Poverty Reduction Strategy Paper.[13] In order to achieve this goal, the Government has been strengthening policies and institutions related to rural electrification. In December 2003, the Rural Electrification Act was ratified to establish the Rural Electrification Authority (REA) and to improve the management of REF.[13] The Government, through the Rural Electrification Master Plan (REM), has set a target to increase electrification rates to 66 per cent of households by 2030, of which 90 per cent would be for urban areas and 51 per cent for rural areas.[13]

Despite Zambia's vast renewable and non-renewable energy sources, few of these have been developed to improve the attractiveness of the energy sector and to transfer the benefits for the industrial expansion, employment creation and poverty reduction.[14,15] The development of large hydropower plants in Zambia has historically been driven by the industrial needs of energy for mining, whereas, SHP development has historically been initiated to provide power to areas that are far from the national grid, such as areas that were extending from the Southern Province towards the Copperbelt. To date, four SHP plants that are operated by the state are being upgraded and connected to the grid. In recent years, the private sector of small-scale social and industrial developers has also managed to install some micro-hydropower systems.

ZESCO is the main operator in the electricity sector in Zambia, with the functions of generation, transmission and distribution. In some rural areas, where ZESCO's national grids do not cover, small IPPs and non-governmental organizations are supplying electricity with either small hydropower or diesel power plants through the isolated distribution network. Electricity generation by ZESCO mostly comes from the hydropower plants located in southern area of Zambia. ZESCO transmits its power at various voltage levels, namely 330 kV, 220 kV, 132 kV, 88 kV, and 66 kV.[14] These voltage levels are stepped-down to 33 kV and 11 kV for distribution at substations. The main 330 kV transmission lines are running north to south in the middle of the country because the copper mines, which are the largest load centre, are located in the north and the main generation stations are located in the south. Copperbelt Energy Corporation (CEC) has most of the mining and large industrial customers, who are supplied at 66 kV or higher voltage in Copperbelt Province, while small customers within CEC's service area are supplied by ZESCO. In the past 10 years, ZESCO has managed to reduce losses of the power grid from 27 per cent to the current rate of 12 per cent.

Generation for a long time was predominantly hydropower, estimated at 99 per cent, until a 300 MW coal plant was commissioned in 2016. Due to the planned renewable energy projects, solar power is expected to be commissioned in the short term leading to the generation mix, by 2019–2022, is expected to take the form shown below in Figure 4.

Figure 4.
Projected generation mix by 2022 (%)



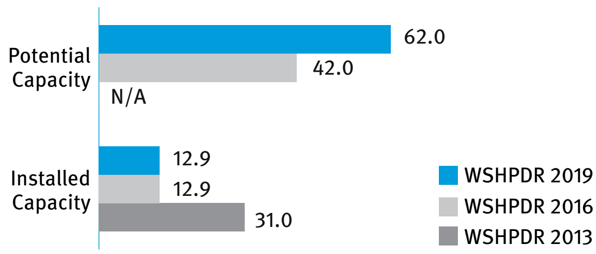
Source: ZESCO[10]

With electricity demand in Zambia projected to increase at a rate of about 4 per cent per annum,[10] and the current national and regional power deficit, there is need to deal with various bottle-necks in the hydropower development process in Zambia. The updated ZESCO hydropower database since 2016 indicates that the statistics of hydropower potential was in the order of 8,000 MW,[9] however only 2,388 MW has been developed.[14]

Small hydropower sector overview

Zambia classifies SHP plants as those units between 0.5 MW to 20 MW. Plants less than 0.5 MW are regarded as micro-hydropower plants. Plants from 20 MW to 100 MW are classified as medium hydropower plants and those having installed capacities greater than 100 MW as large hydropower plants.

Figure 5.
Small hydropower capacities 2013/2016/2019 in Zambia (MW)



Source: *WSHPDR 2013*,[17] *WSHPDR 2016*,[18] CSO[9]

Note: The comparison is between data from *WSHPDR 2013, WSHPDR 2016* and *WSHPDR 2019*.
Note: For SHP up to 10 MW.

Figure 5 shows the SHP capacities, based on the up to 10 MW definition, and the comparisons between the *World Small Hydropower Development Report* (*WSHPDR*) *2013*, *WSHPDR 2016* and *WSHPDR 2019*. The potential capacity in Figure 5 is based on the planned SHP projects up to 10 MW in Zambia. Table 4 lists these projects, based on the Zambian definition of SHP between 0.5 MW to 20 MW. As the projects are incomplete, the installed capacity of Zambia has not increased.

The SHP sector in Zambia is currently undergoing a rehabilitation transformation, scaling-up of old plants and development of new plants are in various stages of project development. As of 2016, and based on the Zambian definition of SHP between 0.5 MW to 20 MW, the total installed capacity for small and micro-hydropower plants stood at 39.7 MW.[9] This is shown in Table 2. ZESCO LTD is currently rehabilitating and up-scaling three SHP plants: Chishimba is being rehabilitated and upgraded from 6 MW to 10 MW; Lusiwasi is being replaced by new plants upstream and downstream with capacities of 12 MW and 86 MW; and Musonda is being rehabilitated and upgraded from 5 MW to 10 MW.

Table 2.
Micro- and small hydropower plants in Zambia (MW)

Project	*Capacity (MW)*	*Remarks*
Mutanda HPP	0.0025	
Mporokoso HPP	0.005	
Sachibondu HPP	0.015	
Mangango HPP	0.017	
Mayukwayukwa HPP	0.028	
Lwawu HPP	0.05	
Nyangombe HPP	0.073	
Zengamina HPP	0.70	
Shiwangandu HPP	1	
Musonda HPP	5	Being upgraded to 10 MW
Chishimba HPP	6	To be upgraded to 10 MW
Lusiwasi HPP	12	To be upgraded to 84 MW
Lunzua HPP	14.8	
Katibunga HPP	N/A	
Total	**39.6905**	

Source: ZESCO LTD,[10,] Ministry of Energy[13]

Table 3.
Planned small hydropower projects in Zambia (MW)

No	*Project*	*Capacity (MW)*	*Status*
1	Namundela	4.8	Feasibility
2	Kapamba	12.0	Feasibility
3	Kalepela	4.0	Feasibility
4	Mumbuluma	8.0	Feasibility
5	Mujila	7.0	Packaging
6	Kasanjiku	0.4	Construction
7	Kaombe	7.4	Pre-feasibility
8	Kakonko	7.0	Pre-feasibility
9	Mululwe	3.5	Pre-feasibility
10	Mbulumotuta	11.0	Pre-feasibility
11	Mwasha	5.0	Pre-feasibility
12	Malisa	10.0	Pre-feasibility
13	Chavuma	14.0	Feasibility
14	Chanda	1.0	Feasibility
15	West Lunga	2.5	Packaging
16	Zengamina	0.7+0.7	Packaging
Total		**99**	

Source: ZESCO LTD,[11] Ministry of Energy[13]

The SHP potential in Zambia remains inaccurately recorded, mainly due to the lack of a comprehensive and updated database, particularly one dealing with SHP.

Renewable energy policy

The overall responsibility for energy administration and policy formulation lies with the Ministry of Mines Energy and Water Development (MMEWD). There are other units within the MMEWD that play a significant role in the electricity sector. The Office for Promoting Private Power Investment (OPPPI) has the role of promoting private investment in the development of power projects. The Rural Electrification Authority (REA) is a statutory body created under the MMEWD through the enactment of the Rural Electrification Act No. 20 of 2003. It has the role of promoting utilization of available rural electrification technological options and to enhance the contribution of energy to develop agriculture, manufacturing, mining and other economic activities in rural areas. The Energy Regulation Board (ERB), formed through an Act of Parliament of 1995, is responsible for licensing generating plants, regulating transmission and distribution operations, regulating power tariffs, especially retails, and mediating conflicts regarding these issues. ZESCO Limited is the public power utility, with the functions of generation, transmission and distribution.

In Zambia, there are three main statutes related to rural electrification: Electricity Act (ratified in April 1995 and amended in December 2003), Energy Regulation Act (ratified in April 1995), and Rural Electrification Act (ratified in December 2003). The Electricity Act was ratified to regulate the generation, transmission, distribution and supply of electricity. The Energy Regulation Act was ratified to establish the Energy Regulation Board and to define its functions and responsibilities and to manage the licensing of undertaking for the production of energy or production or handling of certain fuels. The Rural Electrification Act was ratified to establish Rural Electrification Authority and to define its functions, to re-establish the Rural Electrification Fund (REF) and to provide for matters connected with or incidents to the foregoing.

The policy framework governing renewable energy in Zambia is driven by the National Energy Policy. It was formulated in 1994, and it sought to promote optimal supply and utilization of energy for socio-economic development in a safe and healthy environment. Due to a realization of the strategic nature and integrated nature of energy in economic development, the National Energy Policy has been revised to ensure that the role of energy in relation to other economic dynamics are taken care of. In particular, emerging cross cutting aspects related to sustainable industrial development were not addressed in the National Energy Policy of 1994.

The current National Energy Policy of 2008 recognizes the critical role played by renewable energy in poverty alleviation and national development. In 2016, the ERB completed developing a regulatory framework for renewable energy.[9] The Renewable Energy Regulatory Framework (RERF) was developed in line with the National Energy Policy (2008), the Biofuels Regulatory Framework, the Regulatory Framework for Off-Grid Systems, the REFIT Strategy and other relevant legislation. These documents individually strive to facilitate the implementation and diversification of the energy sector in order to promote renewable energy technologies and improve access to modern forms of energy. The RERF puts all these requirements in one document covering renewable energy-based electricity generation from stand alone and off-grid systems, with the aim of achieving the following:

- Facilitating the implementation of Government policy to diversify the energy mix and provide modern forms of energy to rural communities;
- Consolidating and rationalising existing regulatory frameworks;
- Promoting investment by having a clear regulatory framework that outlines the entry requirements into the sector;
- Providing clear internal guidelines to facilitate their deployment.[9]

In 2016, the Government of Zambia and Kreditanstalt für Wiederaufbau (KfW) initiated the Global Energy Transfer Feed-In Tariff (GETFIT) programme.[9] The programme is designed to leverage private sector investment into renewable energy generation projects. The GETFIT programme in Zambia intends to fast-track a portfolio of up to a maximum of 20 MW each, small-scale renewable energy generation projects, including SHP projects promoted by private developers. It is envisioned that the full implementation of the GETFIT programme will be done as soon as the REFIT Strategy is launched and is also contingent on the finalization of the following support mechanisms:

- Development of the procurement guidelines;
- Development of the Standard Implementation Agreement;
- Agreeing the quantum of GETFIT subsidy on the REFITs.[9]

In order to develop a balanced REFIT, various methodologies and options were considered. These are the cost-based, value based and fixed price incentive approaches. Zambia shall apply a REFIT methodology which follows the cost-based approach. The key attributes of this approach are to implement a rate of return methodology and payment calculated using costs and return expectations of project investors. The ERB's general tariff approach is based on the rate of return methodology, which is widely used by the regional and international regulators to determine administered prices. The main principle of the rate of return methodology is that revenues of the regulated entity have to cover the operating and maintenance expenses, taxes and depreciation and have to ensure a fair rate of return (profit) on assets. ERB's rate of return methodology is based on the underlying cost of supply including a fair return on investment by the licensee. This approach is consistent with the cost-based approach for determining REFIT.[19]

The licence to generate electricity (renewable energy) is to be issued by the ERB. The generation license essentially grants the producer the right to develop finance, construct and operate the power plant, as well as the right to sell the electricity to the off-taker. ZESCO shall be the designated buyer of all the power delivered under the Zambia REFIT program. The details of the off-take arrangement shall be set out in a standardized, technology-neutral power purchase agreements (PPA). The term of the PPA shall be at least 20 years from commercial operation date.[20]

Barriers to small hydropower development

The Zambian SHP industry presents great opportunities for investment and growth. However, it also faces challenges that include, among others, the following:

- Water resources development and management: Lack of hydrological data necessary to adequately asses the available energy on the small river basins;
- Energy policy: Lack of a comprehensive energy policy to deal with requirements of private plants interfacing with the national grid, for example feed-in-tariffs have affected the process of private sector participation in hydropower generation. The participation of the private sector in the development of new small projects is vital for the development of rural districts;
- Transmission of power: The challenge of the cost of transporting renewable energy generated electricity through the transmission system to the consumption centres of the country affects the bankability of projects considering that suitable hydropower potential is mainly located in remote areas of Zambia;
- Tariff structure and return on investment: The tariff structure in Zambia is still not reflecting the real cost of investment;
- Financing: access to the capital markets for the general local private sector investors remains a challenge to new entrants in the hydropower industry. Due to the high capital investments required in hydropower, the development of SHP plants has not progressed at the pace required to meet various load requirements;
- Inability to attract investment: the challenges related to energy policies, feed-in-tariffs and cost reflective tariffs directly affect the ability to attract investment;
- Access to sites: the poor road networks in rural areas makes it difficult and expensive to carry out any work.[9]

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1.1.15 Zimbabwe

Shorai Kavu, Ministry of Energy and Power Development

Key facts

Population	16,530,000[1]
Area	390,757 km^2 [2]
Climate	The climate in Zimbabwe is markedly varied by altitude. There is a dry season, which includes a short cool season from May to September when the whole country has very little rain. The rainy season is typically from November to March.[2] In 2015, the lowest temperature was in June at 16 °C and the highest temperature was in December at 26 °C. The average temperature was 22 °C.[16]
Topography	Zimbabwe is a landlocked country lying wholly within the tropics. It straddles an extensive high inland plateau that drops northwards to the Zambezi valley, where it borders Zambia, and drops southwards to the Limpopo valley and the border with South Africa.[2] Zimbabwe has an average elevation of 1,500 metres above sea level and the highest peak is in the Nyangani Mountains to the north-east of the country at 2,592 metres.[17]
Rain pattern	The maximum rainfall is received in the eastern highlands, with annual rainfall of more than 1,000 mm. The Highveld receives an annual average of more than 500 mm. Southern Africa's climate and rainfall patterns have varied greatly for at least the last three centuries, leading to recurrent droughts of varying severity.[2]
Hydrology	Zimbabwe has six drainage basins. The largest being the Zambezi and the Limpopo basins. The western parts of Matabeleland is connected to the Okavango inland drainage basin through the Nata River. Parts of Mashonaland and parts of Masvingo drain through the Save River into the Indian Ocean. Two other drainage basins covering parts of Manicaland, and drain into the Indian Ocean through Mozambique are the Pungwe River to the north and the Buzi River to the south.[2]

Electricity sector overview

In 2015, the total electricity generation in Zimbabwe was 9,394.2 GWh. Figure 1 shows the electricity generation in Zimbabwe by source, with hydropower as the largest contributing source (53 per cent) to Zimbabwe's annual electricity generation.

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

Source: ZERA[9]

Table 1 shows the electricity produced by these power plants and shows that the electricity production in 2015 of the Zimbabwe Power Company (ZPC) power plants decreased from the 2014 levels. This was mainly because of the reduced generation at Kariba Hydro due to water rationing following a drought and a number of unplanned outages from the aging coal fired thermal power plants.

Table 1.
Energy produced by Zimbabwe Power Company power generation plants (GWh)

Power plant	2014 Actual production (GWh)	2015 Actual production (GWh)
Kariba Hydropower	5,403	4,938
Hwange Thermal (coal)	3,821	3,721
Harare Thermal (coal)	216	209
Bulawayo Thermal (coal)	167	174
Munyati Thermal (coal)	176	173
Total	**9,783**	**9,215**

Source: ZERA[9]

Table 2 shows the electricity production of independent power producers (IPPs), indicating a slight increase in total production from 2014 to 2015.

As of 2017, Zimbabwe had total available electricity generation capacity of 1,760 MW, of which 750 MW was from Kariba South hydropower plant, 750 MW from Hwange thermal power station, a combined 170 MW from small coal-fired thermal plants, namely Harare, Bulawayo and Munyati, and 36 MW were contributed by IPPs (see Table 3). There was also power generated from bagasse by sugarcane and ethanol producing firms, with a total installed capacity of 90 MW, however, this was for the private use of those firms.[7]

Table 2.
IPP electricity generation (GWh)

Producer	*Technology*	*Generation (GWh)*			
		2012	*2013*	*2014*	*2015*
Nyangani Renewable Energy (Pungwe, Nyamingura & Duru)	Mini-hydro	2.6	14.2	28.8	51.2
Hippo Valley Estaes	Biomass (Baggasse)	55.2	70.2	50	34
Triangle Limited	Biomass (Baggasse)	111.4	95.6	94.2	87.5
Border Timbers	Biomass (Sawmill waste)	-	0.2	0	0
Chisumbanje	Biomass (Baggasse)	-	-	-	6.5
Total		**169.2**	**180.2**	**173**	**179.2**

Source: ZERA[9]

The available capacity shown in Table 3 is lower than installed capacity due to the aging of generating equipment at the coal thermal power plants. The aging transmission equipment may disturb dispatch of grid connected small hydropower (SHP) plants. And, due to supply constraints, there is a difference between achievable and available capacity.

Table 3.
Internal generation and available capacity

Source	*Installed capacity (MW)*	*Available capacity (MW)*	*Achievable capacity (MW)*
Hwange	920	750	525
Kariba	900	750	700
Small Thermals	270	170	20
IPPs	124.9	36	11
Total	**2,214.9**	**1,760**	**1,245**

Source: Zimbabwe Power Company[7]

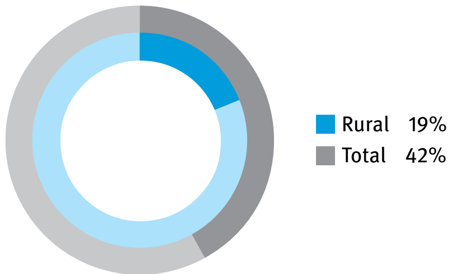
Note: Data as of 18 December 2017.

ZPC has completed the 300 MW expansion project of the Kariba South hydropower plant. The first 150 MW unit of this phase was commissioned in December 2017, while the second was commissioned in March 2018, bringing the total installed capacity of the plant to 1,050 MW. Work is also underway to expand the Hwange Thermal Power Station by 600 MW.[7]

A 2.5 MW solar power plant, the Riverside Solar Power Plant, was commissioned in February 2017. This is an IPP-owned plant and the first grid connected solar power plant in the country. This plant has been connected and running since January 2018, however, generation data was not available for it and, therefore, not included in Figure 1. A number of upcoming IPP-owned projects have been licensed and are yet to reach the financial closure. These include the 3 x 100 MW solar power plants for ZPC and some 14 more owned by private players.[8]

According to the Ministry of Energy and Power Development (MOEPD) statistics, the country's electrification rate was at 42 per cent as of 2017. The 42 per cent comprised of 87 per cent electrification rate for urban areas and 19 per cent for rural (Figure 2).[18]

Figure 2.
Electrification rate in Zimbabwe (%)



Source: Ministry of Energy and Power Development's statistics[18]

The main sources of energy in Zimbabwe are hydroelectric power, coal and petroleum fuels. In rural parts of the country, 80—90 per cent of the people depend on wood fuel and kerosene for cooking and lighting.[5] Food processing tasks like milling grain are usually carried out with a diesel-powered system with a few now using electricity. Although Zimbabwe is endowed with an abundance of renewable energy resources like solar, wind, biomass and SHP, inclusive of run-of-river schemes and inland dams, these are still not fully utilized.[6] All petroleum fuels are imported. The demand for petroleum fuels is about 2.5 million litres of diesel and 1.5 million litres of unleaded petrol per day and 15 per cent (E15) mandatory and 85 per cent (E85) voluntary ethanol blend.

The energy sector in Zimbabwe is overseen by MOEPD.[3] Below MOEPD is the Zimbabwe Energy Regulatory Authority (ZERA), which ensures fairness in the sector. ZERA oversees the operations of Zimbabwe Electricity Supply Authority (ZESA) Holdings Private Limited Subsidiaries, the oil companies and IPPs. Zimbabwe Electricity Transmission and Distribution Company (ZETDC) and ZPC are subsidiary companies of ZESA Holdings, and the oil companies include both public and private companies. In addition, ZESA ensures fair tariffs and other service provision quality levels to the consumer.[4] Figure 3 illustrates the governance structure of the energy sector as explained above.

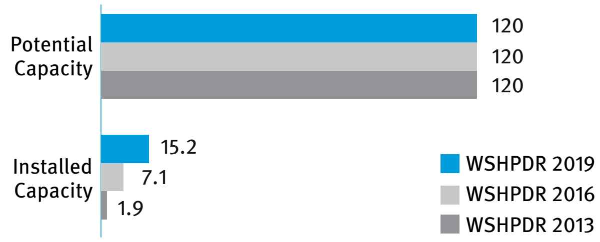
Figure 3.
Zimbabwe energy sector governance structure

Source: ZERA[4]

Small hydropower sector overview

SHP in Zimbabwe is defined as installed capacity of up to 30 MW.[5] Zimbabwe has a potential capacity of 120 MW from run-of-river systems and inland dams.[6] By 2017, the installed capacity of SHP up to 10 MW had reached 15.2 MW, mainly from run-of-river schemes in the Eastern Highlands. The increase from the *World Small Hydropower Development Report (WSHPDR) 2016* is due to previously incomplete data. Figure 4 shows the potential and installed capacities of hydropower in Zimbabwe.

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



Source: Ministry of Energy and Power Development,[6] ZERA,[9] *WSHPDR 2016,*[10] *WSHPDR 2013*[11]

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

Most of the micro-schemes were installed by Practical Action and Oxfam as donations, while the SHP schemes that are connected to the grid were completed by independent power producers (IPPs) such as, Nyangani Renewable Energy (NRE) and Kupinga Hydro. Many more IPPs were licensed by ZERA for different sites and are at different stages of development. The Government is also seeking funds to develop the following sites: Gairezi (run-of-river scheme), Tokwe Mukorsi dam, Manyuchi dam and Ruti dam.[9]

Table 4.
Micro and small hydropower in Zimbabwe (SHP up to 30 MW)

Non-operational		*Operational*		*Under development (Licenced- awaiting financial closure)*	
Name of plant	*Size (kW)*	*Name of plant*	*Size (kW)*	*Name of plant*	*Size (kW)*
Chitofu	20	Mutsikira	3	Ruti	960
Dazi	20	Nyafaru	20	Manyuchi	1,400
Svinurai	30	Chipendeke	30	Immaculate Technologies	1,600
Nyamarim-bira	30	Sithole Chikwati	30	Mutambara	1,600
Aberfoyle	35	Ngarura	30	Nyahode	1,700
Kuends	75	Nyamwanga	30	Odzani	2,400
Himalaya	80	Claremont	300	Orsbone	3,000
Rusitu	750	Nyamingura	1,100	Claremont	3,000
		Kupinga	1,600	Tsanga	3,300
		Duru	2,200	H.T.Gen	3,300
		Hauna	2,300	Great Zimbabwe	5,000
		Pungwe A	2,750	Tokwe Mukorsi	15,000
		Pungwe C	3,750	Gairezi	30,000
		Pungwe B	15,000		
Total	**1,040**		**29,143**		**72,260**

Source: Zimbabwe Energy Regulatory Authority,[9] *WSHPDR 2016,*[10] Jonker Klunne[12]

As can be seen from Table 4, based on the up to 10 MW definition of SHP, the total capacity under development is 27.26 MW and the total installed capacity is 15.183 MW. Finally, there is 1.04 MW of non-operational systems because these systems have old equipment that now require refurbishment.

Due to the effect of climate change on the rainfall pattern in Zimbabwe and the region, the design of SHP schemes should ensure climate proof systems. The recurrence of droughts in the region means reduction in run-of-water, thus having a greater impact on micro- and small hydropower systems, with significant impacts to be felt in off-grid systems. The off-grid systems will need to be complemented by other energy sources to ensure reliable electricity supply to relevant loads. Hybrid systems, such as combining hydropower with solar or wind and or diesel generators, depending on the availability of resources in a given area, are recommended.[15]

Renewable energy policy

The country has an Electricity Act of 2002 which allows independent power producers (IPPs) to develop power generation plants.[3] There is also a National Energy Policy (NEP) that was launched in 2012, which summarises the potential of SHP in the country and encourages the increased use of renewable energy sources in the country's energy supply mix.[3] The NEP is also supported by the country's economic blue print, the Zimbabwe Agenda for Sustainable Socio-Economic Transformation (ZIMASSET). The above documents, however, do not elaborate much on development of renewable energy like SHP, thus the country is currently developing a Renewable Energy Policy (REP).

The REP is being developed to create an environment that promotes investment in renewable energy sources like SHP schemes and other renewable energy sources, on- and off-grid systems. Currently, tariffs for SHP schemes are negotiated on case by case basis. ZERA developed some feed-in-tariffs, which have yet to be approved by the Government.[9]

Some climate records in the country have demonstrated that Zimbabwe is already experiencing the effects of climate change, especially rainfall variability. The induced water stress threatens to reduce the run-off necessary to sustain SHP schemes, especially run-of-river type.

Zimbabwe, through the Ministry of Environment, Water and Climate (MEWC), has prepared and submitted up to the third National Communications of the United Nations Convention on Climate Change (UNFCCC). A Climate Response Strategy was also done for the country, along with a Climate Policy. The country also ratified the Paris Agreement and has submitted Nationally Determined Contributions (NDCs), with hydropower development as one of the measures to mitigate and adapt to climate change effects. It is also worth noting that future hydropower development in Zimbabwe will need to ensure robustness and capability for survival of the climate change effects.

Barriers to small hydropower development

Policies and regulations have a bearing on the rate of development of SHP in a country. From 2011, when ZERA came into existence, followed by the NEP, the trend of SHP development has been rising every year. Greater impact is expected when the REP comes into effect. The following are the main barriers to SHP development:

- The effect of extreme weather conditions;
- Lack of feed-in-tariffs (FIT) and standard procurement methods: currently tariffs are negotiated for on a case by case basis;
- High costs of local funding: local banks offer short-term loans at high interest rates;
- Difficulties in accessing foreign funding by most potential developers: very few IPPs have managed to reach financial closure for an SHP project;
- Lack of funding for feasibility studies to ensure bankability of projects: most project sites fail to attract funding due to unavailability of bankable feasibility studies;
- No locally manufactured equipment: all turbines, generators and control equipment are imported.

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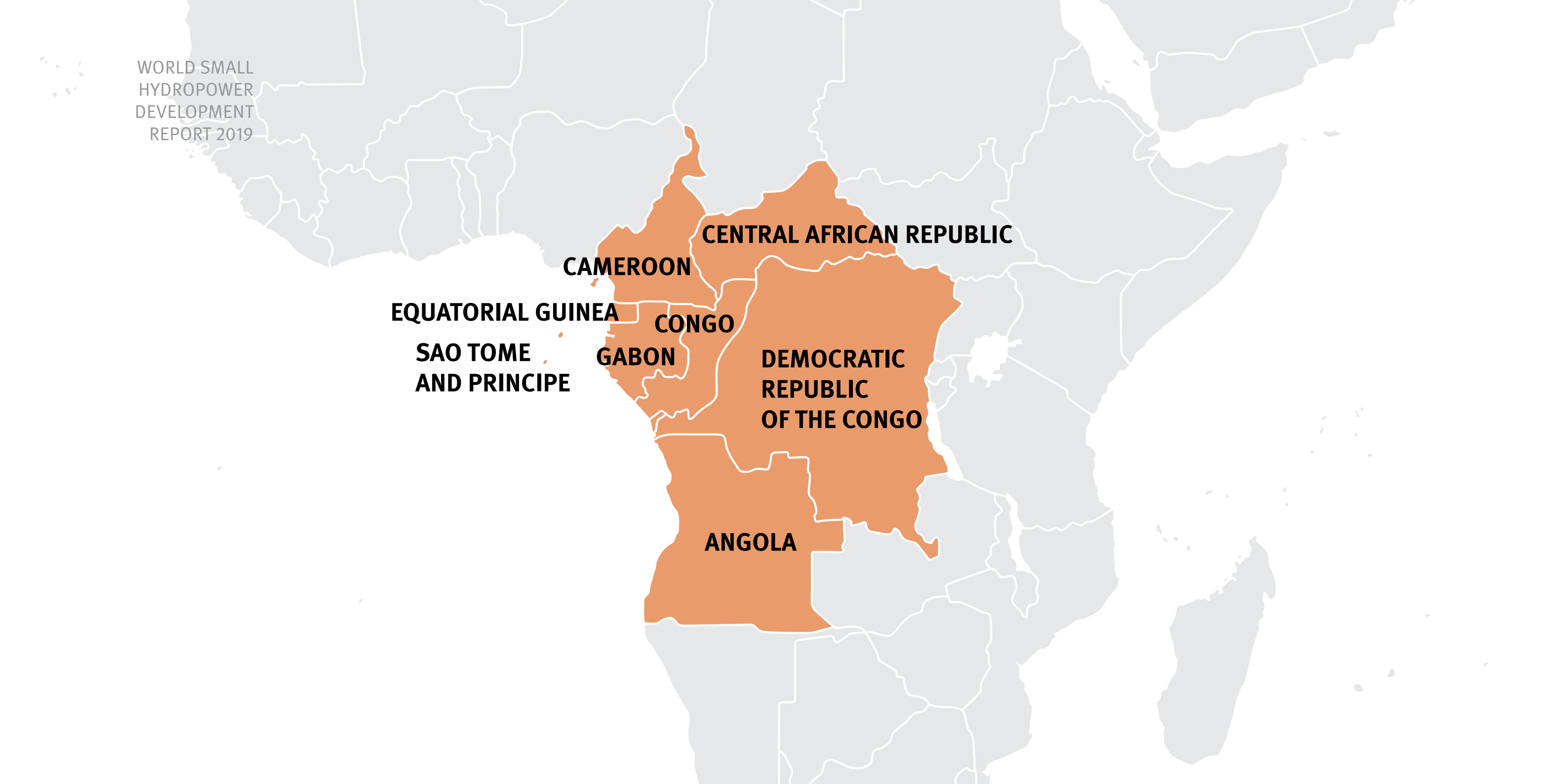


1.2 Middle Africa

Phillip Stovold, Kaboni Energy Ltd; and International Center on Small Hydro Power (ICSHP)*

Introduction to the region

According to the United Nations (UN), the geographic region of Central Africa (or Middle Africa) contains nine countries: Angola, Cameroon, the Central African Republic, Chad, Congo, the Democratic Republic of the Congo, Equatorial Guinea, Gabon and Sao Tome and Principe. This report will cover all countries of the region, except for Chad. An overview of eight countries of Middle Africa is given in Table 1.

Climate and rainfall patterns vary considerably across the region. Rainfall is relatively intense and reliable in the central equatorial and coastal areas but diminishes and becomes variable in the most northern and southern regions. In the centre of the Congo basin, along the coast of Gabon and on the mountain summits bordering the Western Rift Valley, the annual rainfall exceeds 2,000 mm, while in the coastal region of Cameroon it can reach up to 3,850 mm per year.[6]

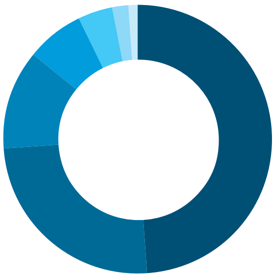
The topography of Middle Africa is characterized by wide plateaus of varying relief that, in turn, define the hydrology of the region. The Congo River basin, second only to the Amazon in terms of its water flow, is the largest river basin in Africa and covers an area of 3.7 million square kilometres. The Congo River has the largest water discharge of any river in Africa, followed by the Zambezi, the Niger and the Nile. Some fragments of northern Middle Africa are situated within the Chad River basin.

Middle Africa holds great hydropower resources, the potential of which is enough to supply the entire continent, and progress is being made in developing the larger-scale hydropower resources in several countries. Nevertheless, to date, some countries in the region have very low electrification rates, with significantly worse rates in rural areas. As such, in the Central African Republic and the Democratic Republic of the Congo only 8 and 15 per cent of the population, respectively, have access to electricity. The electrification rates in the other six countries included in the present report exceed 40 per cent, reaching 91 per cent in Gabon. Another challenge for the region is poor transmission and distribution networks that are in dire need of maintenance.

Hydropower remains an important source of electricity generation in the region, accounting for almost 66 per cent of the region's energy mix. The majority of the 6.5 GW of installed hydropower capacity comes from large-scale schemes, whereas the installed capacity of small hydropower (SHP) up to 10 MW stands at 114 MW. Of the region's total installed SHP capacity, the Democratic Republic of the Congo accounts for 49 per cent (Figure 1).

* *WSHPDR 2016* updated by ICSHP

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



Source: *WSHPDR 2019*[3]

Table 1.
Overview of countries in Middle Africa

Country	*Total population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Angola	29.8	35	40	3,800	9,764	2,365.0	5,192
Cameroon	23.4	44	60	1,665	6,382	732	4,404
Central African Republic	4.6	59	8	29	171	29	170
Congo	5.3	34	57	610	N/A	228	N/A
Democratic Republic of the Congo	89.6	56	15	2,931	N/A	2,812	N/A
Equatorial Guinea	1.3	28	68	390	1,046	180	650
Gabon	2.0	11	91	452	2,329	170	821
Sao Tome and Principe	0.2	28	65	32	101	3	6
Total	**156.2**	-	-	**9,909**	**19,793**	**6,519**	**11,243**

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

Small hydropower definition

Most of the countries in the region define SHP as plants with a capacity of up to 10 MW, whereas Congo, Equatorial Guinea and Gabon lack an official definition of SHP. For these three countries, this report will use the definition of up to 10 MW (Table 2).

Regional small hydropower overview and renewable energy policy

While the region's total installed SHP capacity stands at 114 MW, the individual countries' installed SHP capacities range from 0 to 56 MW (Table 2). The regional leader in terms of SHP potential is Cameroon with an estimated 970 MW of available potential. The total potential of SHP up to 10 MW in Middle Africa is estimated to be 1,856 MW, of which 6 per cent has been developed to date (Figure 2). However, a number of countries still lack a comprehensive estimate of their SHP potential, hence, the actual potential in the region might be higher. Compared to the *World Small Hydropower Development Report (WSHPDR) 2016*, the region's installed capacity increased by approximately 9 per cent, with the most significant changes in absolute terms reported by the Central African Republic, while the installed capacity of Gabon decreased (Figure 3).

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

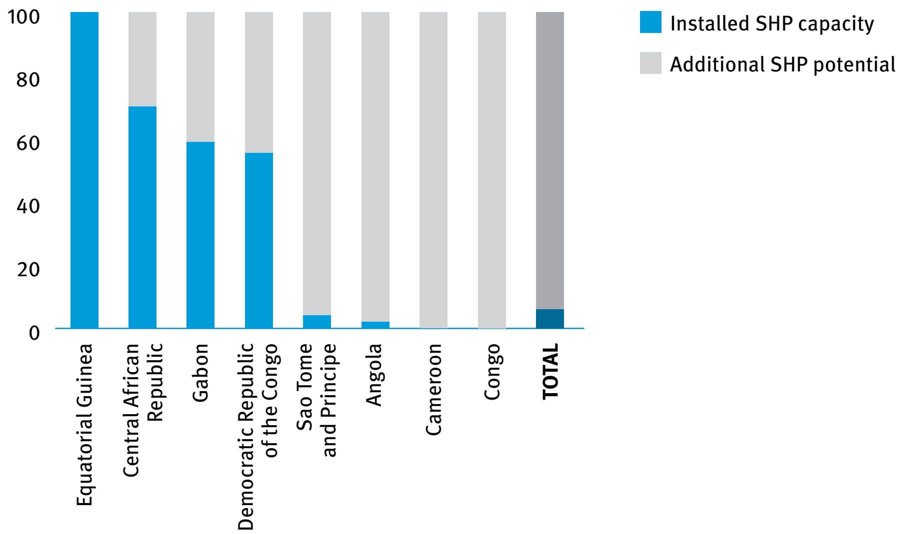
Table 2.
Small hydropower capacities in Middle Africa (local and ICSHP definition) (MW)

Country	*Local SHP definition*	*Installed capacity*	*Potential capacity*
Angola	up to 10	13.1	600.0
Cameroon	up to 10	1.0	970.0
Central African Republic	up to 10	28.8	41.0
Congo	-	0	65.0
Democratic Republic of the Congo	up to 10	56.0	101.0
Equatorial Guinea	-	7.5	7.5*
Gabon	-	4.6	7.8
Sao Tome and Principe	up to 10	2.7	63.8
Total		**114**	**1,856**

Source: *WSHPDR 2019*[3]

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

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



Source: *WSHPDR 2019*[3]

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

The installed capacity of SHP in **Angola** is 13.12 MW coming from four plants. Since the *WSHPDR 2016*, installed capacity has slightly increased. As part of the 2025 Angola Energy Strategy, the Ministry of Energy and Water identified 100 locations suitable for the construction of 600 MW of SHP. Of this potential, roughly 2.2 per cent has been developed to date. The Government of Angola is planning further refurbishment procedures on the existing plants. In addition to a large hydropower potential, Angola also has a significant potential for the use of other renewable energy sources, including solar, wind and biomass.

No comprehensive and accurate data on the installed SHP capacity of **Cameroon** is currently available. However, it is estimated that it is at least 1 MW. Thus, compared to the results of the *WSHPDR 2016*, installed capacity doubled. The total potential is estimated to exceed 970 MW. Five potential sites with a combined capacity of 16.1 MW are targeted for development through private initiatives by 2021.

The **Central African Republic** has 28.8 MW of SHP installed capacity. The increase since the the *WSHPDR 2016* is due to the construction of the Boali III hydropower plant with an installed capacity of 10 MW. In addition to the new plant, there are two other SHP plants with installed capacities of 8.75 MW and 10 MW. Moreover, it is believed that off-grid plants as well as multiple micro- and pico-hydropower units also exist, however, there is no data available with regards to their installed capacity or generation potential at the moment. The country's SHP potential is estimated at 41 MW, of which 70 per cent has been developed.

Since the *WSHPDR 2016*, **Congo** has not developed any SHP plants and still has only large-scale hydropower plants in its energy mix. Based on two studies carried out in the country, the potential of SHP in Congo should be at least 65 MW. However, no exact and comprehensive estimate of the total potential is available, and the SHP potential in the country is expected to be more significant.

The **Democratic Republic of the Congo** has approximately 56 MW of SHP installed capacity, of which roughly 6 MW is from plants up to 1 MW. However, the available data on SHP varies by source, and the number of privately owned and operated SHP plants has not been fully identified. The potential capacity in the Democratic Republic of the Congo is approximately 101 MW. Approximately 100 potential SHP sites have been identified, but more thorough research could double this amount due to the large number of rivers yet to be surveyed. Compared to the *WSHPDR 2016*, both installed and potential capacity remained unchanged. The promotion of SHP is included in the national electrification plan.

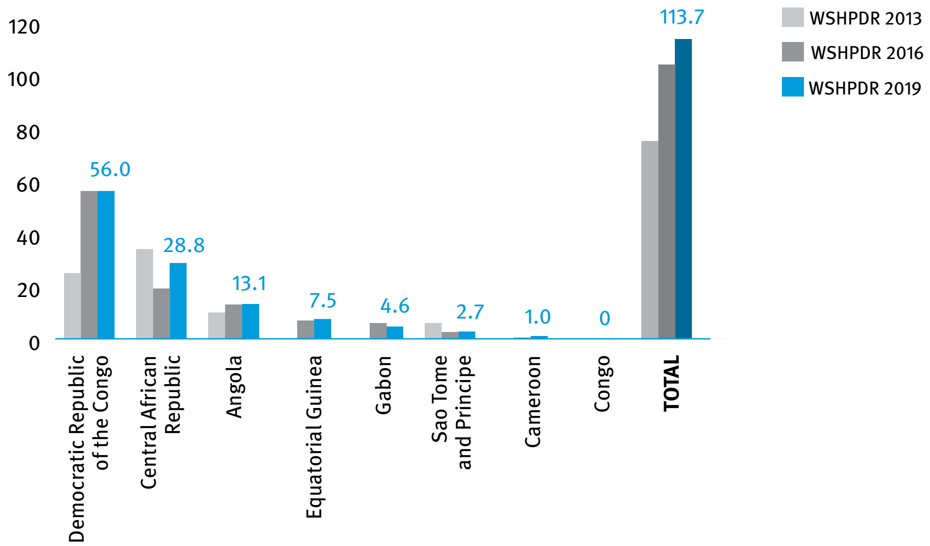
Equatorial Guinea has three SHP plants with a combined capacity of 7.5 MW: the 0.5 MW Musola plant, the 3.8 MW Riaba plant and the 3.2 MW Bikomo plant. The increase of 5 MW installed capacity observed between the *WSHPDR 2016* and *2019* may be due to the previous lack of data on the Musola hydropower plant. The potential for SHP development in the country remains unknown. There are no known plans of future SHP development. Conversely, solar power and large-scale hydropower have seen certain developments.

Gabon also has three SHP plants. Their combined installed capacity is 4.58 MW. The total potential of SHP is unknown, however, based on planned projects, it is possible to conclude that there is at least 7.84 MW of available potential. Compared to the *WSHPDR 2016*, installed capacity decreased by 1.4 MW, due to a decrease in the installed capacity of the Bongolo plant as a result of renovation works. The total potential of hydropower in Gabon is estimated to be up to 8,000 MW, and hydropower is seen as an integral part of the Government's vision for the development of Gabon.

All four hydropower plants operating in **Sao Tome and Principe** are small-scale. Their combined capacity is 2.7 MW. There is a considerable potential for the further development of hydropower resources in the country. This includes 34 exploitable SHP sites across the two islands with an estimated capacity of 61.1 MW. With the support of the World Bank and the European Development Bank, the Rio Contador hydropower plant is undergoing modernization works, which will increase the plant's capacity from the current 2 MW to approximately 4 MW.

Although there is significant political support for renewable energy sources across the region, none of the countries in the region have yet introduced **feed-in tariffs (FITs)**. However, the 2025 Energy Strategy of Angola foresees the introduction of FITs.

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



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

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

Barriers to small hydropower development

A dominant issue in the region is the lack of a transparent, complete and accessible regulatory framework that encourages and facilitates the early stage risk of finance investment for SHP development. For example, Cameroon has a good legislative and policy framework, but lacks the regulations required for its implementation. Investment in the region is often complicated by such factors as automatic rights to land confiscation, which make investment impossible without complicated insurance guarantees. Progress has been made, but the region's environment continues to be difficult for the development of SHP projects, as such projects usually do not have the financial resources required to overcome the significant investment hurdles. Moreover, low retail prices of electricity do not allow for the reimbursement of costs. It should be noted that all these countries experience governance and corruption problems, making small-scale private hydropower project development difficult in the region.

The main barriers for SHP development in **Angola** include limited long-term financing models for private investors, limited access to appropriate technologies in the mini-, micro- and pico-hydropower categories and limited infrastructure for manufacturing, installation and operation of SHP plants.

In addition to financial and technical limitations, SHP development in **Cameroon** is hindered by the availability of vast resources for large-scale hydropower, such that SHP is considered excessive and does not receive consideration and support. The institutional framework in general does not encourage private investment and the country's ongoing crisis prevents the development of SHP in the region with a significant SHP potential.

In the **Central African Republic**, the strong monopoly in the electricity sector disincentives investors, increases the project-related costs and limits the potential profit. SHP is also hindered by the lack of support schemes, trained staff and standards for SHP. Limited financial resources and political unrest might also deter future investment in SHP.

In **Congo**, the regulatory and permitting process is not clearly defined, and the country can already meet its current electricity requirements through large-scale projects. Low electricity tariffs, the lack of local skills to install, operate and maintain an SHP plant as well as the lack of local technology make the sector less attractive than other power projects.

The development of SHP in the **Democratic Republic of the Congo** is limited due to the poor quality of the equipment, or the complete lack of it, low electricity tariffs and the fact that some of the foreseen measures (legislative, institutional, financial) have not been implemented.

In **Equatorial Guinea**, the current primary focus seems to be on the implementation of large hydropower projects, while no intention to disseminate SHP in the country has been made official, besides the refurbishment plans for the existing SHP plants. The legislative framework is imprecise and lacks incentive policies, and training and expertise in SHP technology management and development remain limited.

Similar to other countries in the region, SHP development in **Gabon** is hindered by a lack of local expertise and a regulatory and political framework, inadequate energy, water and transportation infrastructure and high levels of bureaucracy. Other barriers include poor quality of the state services and relatively high labour costs.

The major barriers to SHP development in **Sao Tome and Principe** include a lack of a national strategy for the hydropower subsector, a lack of an Electricity Master Plan and a lack of funding for small, mini- and micro-hydropower projects.

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Angola

1.2.1

Vladimir Russo and João Russo, Holísticos, Lda.

Key facts

Population	29,784,190[1]
Area	1,246,700 km[2]
Climate	The weather in Angola is tropical, with a rainy season in the warmer period (September – May) and a dry season in the cooler period (June – August). Due to its geographical location, weather in Angola can be divided into distinct climatic regions. On the coast there are heavy rainfalls that decrease from north to south, and the average annual temperature is just above 23 °C. The interior zone can be divided as follows: north, with heavy rainfall and high temperatures; Central Plateau, with a dry season and average temperatures in the order of 19 °C; and south, with very high thermal amplitudes due to the proximity to the desert and the influence of tropical air masses.[3,16]
Topography	Topographically, Angola consists of a coastal plain and broad table lands above 1,000 metres in altitude, with a high plateau in the centre and south ranges up to 2,400 metres. The highest point in Angola is Mount Moco, at 2,620 metres in the Huambo Province. There are 47 main hydrographical basins and 30 sub-basins.[16]
Rain pattern	Hot summer months in Angola (June – August) are very dry, with almost no rainfall. The wet season (October – April) has between 100 and 250 mm of rainfall per month.[3,16] The wettest region is the north-east, and the total rainfall decreases southwards and towards the western coast. The average annual rainfall is approximated at 984 mm.[2]
Hydrology	Most of the rivers rise in the central mountains. Of the many rivers that drain into the Atlantic Ocean, the Cuanza and Cunene are the most important. Other major streams include the Cuango River, which drains north to the Congo River system, and the Cuando and Cubango Rivers, both of which generally drain south-east to the Okavango Delta in Botswana. Angola has no sizable lakes.[16]

Electricity sector overview

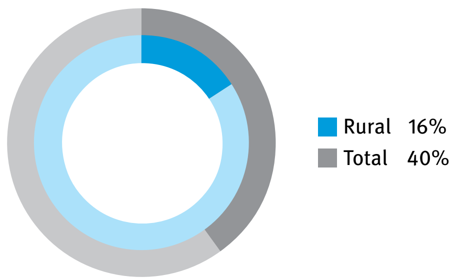
Electricity generation was 9,764 GWh in 2015. Approximately 63 per cent of the electricity generated is from hydropower, while the remaining 37 per cent is produced from thermal plants, running on coal or gas.[5] Figure 1 offers more information on electricity generation by source. According to the World Bank, the electrification rate in 2016 was 40 per cent, with only 16 per cent of the rural population having access to electricity.[6] At the end of the first half of 2017, the National Company for the Distribution of Electricity (ENDE) served 1,305,000 customers in 73 municipalities.[6] This rate of electrification is not homogeneous throughout the country, standing at only 75 per cent in Luanda and only 8 per cent in Bié. Of the 1,305,000 customers currently served by ENDE, only 289,000 are provided with electricity through prepaid meters.

By September 2017 there was an installed capacity of 3.8 GW, of which 2.8 GW were available for distribution. The heightening of Cambambe and the first Laúca Dam turbines comprised an important component of the available capacity. By the end of 2018, the installed capacity was expected to grow to 6.4 GW and available capacity to 5.5 GW, particularly due to the operation of the Soyo combined cycle plant and the other Laúca turbines.[12]

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

Source: UN[5]

Figure 2.
Electrification rate in Angola (%)



Source: WB[6]

Between 2008 and 2014, electricity consumption in Angola recorded an average annual growth rate of 15 per cent. The consumption of electricity reached 9.48 TWh in 2014, excluding the repressed demand and the demand supplied for self-consumption. Consumption is still highly concentrated in the northern region, which accounted for approximately 78 per cent of the total electricity consumption in the country in 2014.[4] It is estimated that household consumption accounts for about 45 per cent of all energy produced, followed by services with about 32 per cent and industry with approximately 9 per cent. It is estimated that the technical losses in the electricity network are close to 14 per cent due to the current state of conservation of the network.[4]

The Instituto Regulador do Sector Eléctrico (IRSE) is responsible for regulating the energy sector in Angola. It was established by Decree No. 4/02 on 12 March 2002 and plays the role of the regulator of the electricity sector, regulating production, transport, distribution and sale of electricity in the Public Electricity System (SEP). It also regulates the commercial relationship between these different systems. The market prices for electricity are regulated by Presidential Decree No. 4/11, issued on 6 January 2011, which provides the basis for the calculation of the electricity tariffs.[9,16] The design principles of the newly established model intend to strengthen the IRSE's role, to develop a competitive process for both public and private generation and to establish an Independent Transmission Operation, which will also act as a single buyer for all electricity generated in the SEP.[9,16]

Presidential Decree No. 256/11, National Policy and Strategy for Energy Security, established a set of objectives for the electricity sector for 2025 and reinforced the importance of electricity to the country. These goals included, among others, increasing the electrification rate from 30 per cent to 60 per cent, quadrupling generation capacity from the current 2.0 GW to 9.5 GW in 2025, extending more than 2,500 km of lines and substations in the transmission grid, establishing international interconnections, rehabilitating distribution networks and adding more than 1.5 million consumers.[10]

By 2025, strong demand growth is expected to reach 7.2 GW, four times current demand. This expected growth results from electrifying 60 per cent of the population, increasing residential consumption, increasing national wealth through services and the industrialization of the country.[11]

The development of energy transport infrastructures in the period 2013-2017 fell short of what was initially planned, and it was expected that in 2017 the systems in the north, central and south regions would be interconnected and that the Eastern Province capitals would be interconnected by a 220 kV system. The current transport system is characterized by a growing North System, already interconnected with Benguela, and by numerous isolated systems. The interconnection between the Huambo/Bié System and the 400 kV North System is underway, but should only be completed by 2019/2020. The interconnection between Benguela and the North System is built but inoperative because of the urgent need for reactive energy compensation equipment.[12]

The Public Investment Programme for the five-year period 2018-2022 is organized into 21 initiatives structured in three development programmes and subprogrammes, which include the expansion of access to electricity in urban areas, municipalities and rural areas, the optimization and sustainable management of the electricity sector and private participation in the production and distribution of electricity.[13]

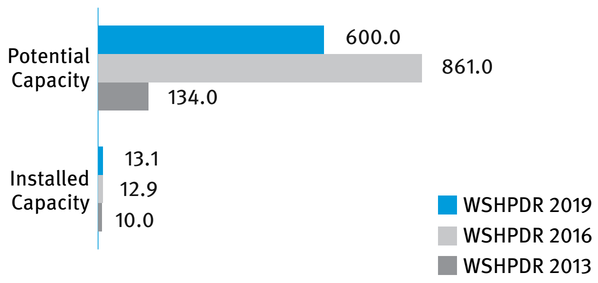
The Private Participation Programme covering the production and distribution of electricity provides three subprograms with 14 initiatives. These subprograms include:

- Thermal projects in Soyo, Lobito and Malembo and hydroelectric production in the Catumbela and Keve Rivers and in the eastern region;
- New and renewable energy (i.e. solar, wind and biomass projects);
- Municipal and rural distribution, particularly in off-grid projects.

Small hydropower sector overview

The definition of small hydropower (SHP) in Angola is up to 10 MW. Installed capacity of SHP in Angola is 13.12 MW, while the potential capacity is estimated to be 600 MW. The decrease in potential capacity between the *World Small Hydropower Development Report* (*WSHPDR*) *2016* and *WSHPDR 2019* is due to more specific data being made available. As part of the 2025 Angola Energy Strategy, the Ministry of Energy and Water of Angola identified 100 locations suitable for the construction of 600 MW SHP plants (up to 10 MW each, installed capacity).[10,14] Between the *WSHPDR 2016* and *WSHPDR 2019*, installed capacity has slightly increased. The Government of Angola is planning further refurbishment procedures conducted on the existent plants in the country.[14]

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



Source: Export.gov,[10] INRH,[14] *WSHPDR 2013*,[15] *WSHPDR 2016*[16]

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

Angola has a large hydropower potential. Hydropower currently provides 63 per cent of the country's electricity (Figure 1). However, facilities were destroyed in the civil war and the Government has not succeeded in keeping the supply in line with expanding demand. The technical hydropower potential is around 80 TWh/year and the economically available hydropower potential is 72 TWh/year (18 GW).[12] SHP potential is currently being assembled into the Atlas of the Hydropower Resource. The study, conducted by the Ministry of Energy and Water, has identified 100 sites to be exploited, with a total potential capacity of 600 MW.[10]

Table 1.
Small hydropower installed capacity in Angola (MW)

SHP site	*Installed capacity (MW)*	*Upgradable to (MW)*
Cunje I	1.62	10
Luachimo	8.40	32
Cuando	1.00	-
Luquixe	2.10	-

Source: INRH[14]

Renewable energy policy

Angola has an evident potential to use renewable energies, particularly from water, solar, wind and biomass. The Strategic Environmental Assessment (SEA) for the Power Development Master Plant in Angola is currently being developed for the Ministry of Energy and Water.[16] This process undertook an environmental and social screening for future energy projects in Angola, which included eight wind farms (Bié, Malanje, Benguela, Huíla, Cuanza Sul, Cuanza Norte and Huambo e Namibe), nine photovoltaic parks (in the Benguela, Namibe, Huíla and Cunene provinces) and one biomass project in Huíla Province.

The Electricity Sector Transformation Programme (PTSE) proposes that power sector reform should evolve through four different phases. The Preparatory Phase (Phase 1), which involves a diagnostic and design study, was completed with the establishment of three new power entities for electricity covering generation, transmission and distribution. It was also completed with the strengthening of the IRSE. The Preparatory Phase also led to a review of tariffs and subsidies, including stabilization and tariff adjustments toward cost reflective value. Phase 2, planned to start in 2018 and continue until 2021, introduces the concept of sector-wide operational efficiency with tariffs approaching the cost of production and includes the incentivized participation of the private sector in renewable energy in rural areas in the form of feed-in tariffs. Partial liberalization of distribution systems and the energy sector, including full participation of independent power producers (IPPs) and the improvement of the energy mix, is expected to be concluded by 2025 as part of Phase 3 of the PTSE.[8,16]

Barriers to small hydropower development

There are still several barriers to SHP dissemination in the country. The main barriers for SHP development in Angola include:

- Limited long-term financing models and private investors to provide renewable energy to customers at affordable prices;
- Limited access to appropriate technologies for mini-, micro- and pico-hydropower;
- Limited infrastructure for the manufacturing, installation and operation, including maintenance, of SHP plants.

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1.2.2

Cameroon

Fombong Matty Fru, Rural World Resources International

Key facts

Population	23,439,189[1]
Area	475,650 km[2]
Climate	Cameroon has a predominantly tropical climate, with a wet season in the warmer period (April – October) and a dry season in the cooler period (November – March). Climate varies with the terrain. It is tropical along the coast and semi-arid and hot in the north. July is the coldest month, with an average temperature of 22 °C, while the hottest month is February, with temperatures averaging 25 °C.[2]
Topography	The south of the country is characterized by dense forests and copious precipitation, which creates an extensive network of rivers. There is an irregular chain of mountains, hills and plateaus known as the Cameroon Range, which extends from Mount Cameroon on the coast, the country's highest point at 4,095 metres, almost to Lake Chad at the northern border. The soils in this region are among the country's most fertile, especially surrounding the volcanic Mount Cameroon. In the south-west, the Atlantic Ocean coastline extends for approximately 420 km.[3]
Rain pattern	Annual rainfall is highest in the coastal and mountainous regions. The wet season starts with the West African Monsoon blowing from the south-west, bringing moist air from the ocean. The wettest regions receive more than 400 mm of rainfall per month, but the semi-arid northern regions receive less than 100 mm per month. The southern plateau region has two shorter rainy seasons: April – June and September – November.[4]
Hydrology	The Sanaga River is the country's longest river at 920 km. Its basin covers approximately 140,000 km², or 30 per cent of the country's territory. The Sanaga and other rivers, namely the Nyong, Ntem, Mungo and Wouri, all flow into the Atlantic Ocean. The Logone River and its tributaries drain into Lake Chad in the north. The Benue, its tributaries (the Faro, Mandara, Alantika and Mayo Kebi), the Katsina-ala, the Menchum and the Donga rivers drain into the Niger River. The Boumba, Ngoko, Nyong and Soo, flowing in the dense forests of the south-east, drain into the Congo River.[4]

Electricity sector overview

Total electricity production in 2015 for Cameroon was estimated at 6,382 GWh, with hydropower contributing 69 per cent (4,404 GWh).[5] In 2016, the total installed capacity for electricity generation stood at 1,665.2 MW, with 56 per cent coming from thermal power and 44 per cent from hydropower (Figure 1).[6] Seventy-eight per cent of this capacity (1,301.2 MW) and all hydropower capacity was owned and operated by ENEO-Cameroon, a further 304 MW was operated by independent power producers (IPPs) Dibamba Power Development Corporation (DPDC) and Kribi Power Development Company (KPDC) (88 MW powered by heavy-fuel oil and 216 MW powered by gas, respectively) and another 60 MW was owned by the company AGGREKO.[6]

The electricity sector of Cameroon is regulated by the Ministry of Energy and Water, which is responsible for implementing government action in the energy sector and overseeing energy sector activities. The Rural Electrification Agency (AER) is in charge of promoting rural electrification and managing the Rural Energy Fund. The AER is also responsible for formulating policy and recommendations on rural electrification for the Ministry of Energy and Water as well as developing management schemes on electricity access for rural communities. The Electricity Sector Regulation Agency (ARSEL) approves electricity tariffs and determines electrical standards. The Agency also monitors the sector's activity and financial equilibrium, examines concession licence applications, authorizes electricity generation and distribution in rural areas, protects consumers, promotes competition and facilitates private sector involvement. The Electricity Development Corporation (EDC) is a state-owned company that is in charge of the development of the electricity sector including all hydropower projects.[7,8]

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

Source: ARSEL[6]

In line with the Electricity Law adopted in 1998 and the complementary Electricity Decree adopted in 2000, in 2001 the state-owned power utility Cameroon National Electricity Corporation (SONEL) was privatized and purchased by the American company AES Sirocco. The new company AES Sonel was granted a 20-year concession. The company was later acquired by the British private equity firm Actis, with 56 per cent of its shares held by Actis and 44 per cent held by the Government of Cameroon. The company was then renamed Energy of Cameroon (ENEO-Cameroon S.A.). ENEO-Cameroon was granted a monopoly over electricity transmission and distribution throughout its concession area until the threshold of 1,000 MW.[7,8]

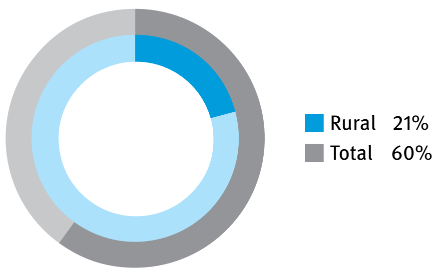
In August 2015, the Ministry of Energy and Water and ENEO-Cameroon signed an amendment to the concessions, which redefined the roles of players in the production and distribution of electricity in the country. This amendment includes provisions regarding the rehabilitation of the Song Loulou Dam, the transfer of storage reservoirs to the Electricity Development Corporation, the transfer of electricity transmission services and management of the transmission grid to the Transmission System Operator Sonatrel (*Société antionale de transport d'électricité*), the redefinition of service quality standards, a new connection plan and an update of the tariff formula.[9] However, one of the major reforms enunciated in the agreement was the introduction of private electricity producers, which eliminated ENEO-Cameroon's monopoly in electricity production and distribution. Nonetheless, the redistribution of roles did not change the role of ENEO-Cameroon as the major owner of electricity generating capacity in the country.[10]

ENEO-Cameroon operates three distinct grids:

- The Southern Interconnected Grid (*Réseau Interconnecté Sud*, RIS): a 225 kV network connecting the major hydropower plants to the aluminium refinery, Yaoundé, Douala and other main areas of consumption;
- The Northern Interconnected Grid (*Réseau Interconnecté Nord*, RIN): a 110 kV and 90 kV network transporting power generated by the Lagdo hydropower plant;
- The Eastern Grid (*Réseau Est*, RE): a low-voltage distribution grid of 30 kV.[7]

The electrification rate in the country in 2016 stood at 60 per cent, with access to electricity in rural areas at 21 per cent (Figure 2).[11,12]

Figure 2.
Electrification rate in Cameroon (%)



Source: World Bank[11,12]

The reliance of Cameroon on 30 ageing diesel power plants as back-up facilities has often led to blackouts and load shedding due to standby generator failures or fuel pilfering. The largest of these plants are located in Bamenda (40 MW), Garoua (20 MW), Douala (15.4 MW) and Youndé (10.8 MW). The addition of three hydropower stations in 2017 – Mekin (15 MW), Lom Pangar (30 MW) and Memve'ele (201 MW) – improved electricity supply and stability. However, the projected additional capacity of 400 MW was not achieved due to the suspended construction of the Kribi gas-powered plant, which was meant to add some 160 MW to the network, and the failure to implement small hydropower (SHP) projects, such as the 2.9 MW Ngassona Falls 210 project.

The hydropower potential of Cameroon is estimated to be approximately 20 GW.[13] However, the current installed capacity represents less than 4 per cent of this technically feasible and exploitable potential. The country is currently building small- and large-scale hydropower and thermal power plants to improve electricity access and achieve at least 4 GW of electricity generating capacity by 2035, as outlined in the Electricity Sector Development Plan (PDSE).[8]

The Government of Cameroon's plan is to install 720 MW of hydropower capacity by 2020. The projects under development and projected include:

- The Mungo River system (estimated 60 MW of grid and off-grid capacity) including some small-scale projects that are going through the permitting process;
- Nachtigal (420 MW), under development by Electricité de France;
- Grand Eweng (1,200 MW);
- Song Mbengue (1,140 MW);
- Kikot (1,000 MW);
- Bini Warak (50 MW);
- Njock (170 MW);
- Ngodi (1,140 MW);
- Song Dong (250 MW);
- Nyamzom (375 MW).[7]

In particular, the Nachtigal Amont hydropower project is a 420 MW hydropower plant on the Sanaga River, located on the Nachtigal falls, approximately 65 km north-east of Yaoundé. The plant is to be equipped with seven Francis turbines of 60 MW each, a 225 kV substation and a double circuit 50.3 km transmission line to transmit the electricity produced to the Nyom 2 connection substation. The commissioning of the first turbine is expected in 2021. The project is being developed by the Cameroonian Project Company, Nachtigal Hydro Power Company (NHPC), whose shareholders are the Government of Cameroon, Electricité de France (EDF) and the International Finance Corporation (IFC).[14]

These projects, among others, are supported by the African Development Bank (AfDB) and the World Bank and are aimed at attracting new investments in the sector.

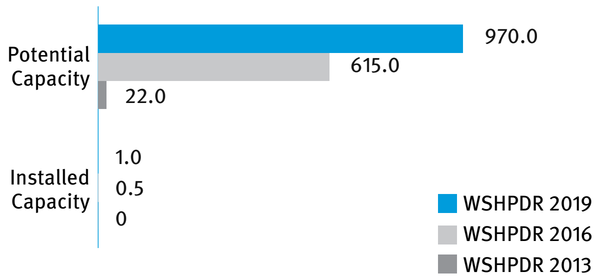
Besides hydropower development, the PDSE 2035 also prioritizes the development of domestic gas reserves. Gas is planned to complement hydropower by bridging the supply gap until additional hydropower capacity has been introduced by ensuring a reliant power supply in the dry season as well as providing an affordable insurance against hydrological risks.[15]

Electricity tariffs are reviewed every five years by ARSEL, who ensures that all changes allow the operator to have average profits in normal conditions of activity. Tariffs are also reviewed in the event when any material changes substantially affect the economic, financial or technical environment in which contracts had been granted.[16] Following the decision of ARSEL No. 0096 of May 28, 2012, the electricity tariffs for residential consumers vary from 84 XAF/kWh (0.15 US$/kWh) to 99 XAF/kWh (0.18 US$/kWh) depending on consumption.[17]

Small hydropower sector overview

The definition of SHP in Cameroon is up to 10 MW. As of 2017, the installed capacity of SHP was at least 1 MW, however, comprehensive and accurate data on total installed capacity are not currently available.[18] Potential is estimated at 970 MW.[19] Compared to the results of the *World Small Hydropower Development Report (WSHPDR) 2016*, installed capacity doubled in the *WSHPDR 2019*, while potential increased by 58 per cent (Figure 3).

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



Source: *WSHPDR 2016*,[16] IHA,[18] RWRI,[19] *WSHPDR 2013*[20]

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

Local non-governmental organizations, such as Action for Equitable, Integrated and Sustainable Development, have helped villages install pico-hydropower systems, often with locally made Pelton turbines, such as the 20 kW unit in Tchouadeng.[21]

The national electrification programmes are predominantly based on large hydropower development and extending the national grid. The 2.9 MW Ngassona Falls (ERD Rumpi project) allocated to contractors was halted. However, in 2018, a total of 90 MW of SHP capacity was at the planning stage in the south, south-west and north-west of the country. Furthermore, new potential SHP sites are constantly being discovered.[19] The country's SHP potential is now estimated to be above 970 MW.[19] The potential for SHP installations below 1 MW per site is estimated at 1.115 TWh and is mainly concentrated in the eastern and western regions of Cameroon.[22] However, this potential is yet to be properly studied to see whether it is technically feasible and economically viable. SHP can be developed by any type of enterprise, yet, so far little has been achieved due to a lack of funds and government support. There are no special financial mechanisms to support SHP projects, therefore, the responsibility falls onto the developers, who lack of expertise in the sector.

Since 2010, many SHP projects have been studied in the western mountain regions and funded by external sources but were scrapped by the Government in favour of large hydropower projects for reasons of cost-per-unit of electricity output. Such sites include Ngassona, Menchum, Katsina-ala and Yoke.

The following SHP sites are targeted for development through private initiatives by 2021:

- Aswenjway (1.5 MW): Low-head (9 metres), run-of-river, private ownership, grid-connected;
- Firsoh (0.5 MW): Medium-head (16 metres), run-of-river, community-owned, stand-alone;
- Meya-1 (9.7 MW): 40-metre head with pumped storage option, run-of-river, grid-connected;
- Mirzam Birtah-1 (2.2 MW): 24-metre head, run-of-river, private industrial application;
- RWRI Micro grid (2.2 MW): SHP, solar PV/biomass hybrid, private industrial application.[19]

In 2016, there were protests by the Anglophone population against the perceived oppression by the Francophone population. The military was deployed against protesters, resulting in deaths, the imprisonment of hundreds of people and thousands fleeing the country. With the crisis situation taking place in the SHP-rich region of Cameroon, financing for SHP projects is not available from local financial institutions. The Government is unable to provide any subsidy or other incentives or financial support, even for community-owned SHP projects, which happen to constitute more than 50 per cent of sites identified so far.[19]

Renewable energy policy

Private producers may now obtain licences and concession agreements to generate electricity from SHP and then sell electricity directly to consumers in non-grid localities or to the national grid. Renewable energy in Cameroon has an important position in the energy mix, with almost half of installed capacity being from hydropower and biomass being an important source of energy as well. Solar and wind power have had a modest impact so far but promising potential has been identified, especially in solar power. The Government promotes the development of renewable energy sources. Any public utility operator has the obligation to connect all renewable energy power producers to the grid upon the producer's request. In the event of rural electrification, priority is granted to decentralized production of renewable energy.
The Government of Cameroon has developed a long-term

PDSE, calling for a 75 per cent electrification rate by 2030 and establishing an order for the implementation of IPPs, thus providing a strong signal for private participation in renewable energy projects in Cameroon. The PDSE also supports the Cameroon Growth and Employment Strategy (2010-2020), with the goal to reduce the cost of electricity production and diversify the country's sources of electricity generation.

The PDSE foresees significant investments in the energy sector, including in renewable energy. Goals include ensuring energy independence through increased electricity production and distribution, in particular through the development of hydropower, and contributing to economic development. Concerning rural electrification, the Rural Electrification Master Plan aims at electrifying 660 localities through grid extension, but also through isolated diesel and mini-hydropower grids.[7]

Barriers to small hydropower development

Cameroon has vast resources for large-scale hydropower, such that SHP is considered superfluous. The installation of large-scale thermal stations is an indication that SHP, even though significantly cheaper and more environmentally friendly, receives little consideration and support in the country. The barriers imposed by the government policy, which considers the long-term effects of the thermal projects and the availability of external funding, include:

- The institutional framework does not encourage private investment;
- Insufficient investment regulations and a lack of standards and quality control mechanisms;
- High difficulty establishing a national or export market for renewable energy, as there are presently no laws regarding energy exports by the private sector and the involvement of the Government in the exercise must follow presidential decrees;
- Unreliable infrastructure;
- Insufficient distribution networks;
- Anticompetitive commercial frameworks;
- Administrative bottlenecks in authorizations, concession rights and licensing;
- Financial insecurity and risk of hindrance to operation and maintenance by high taxes;
- Difficulty in acquiring appropriate funding and technology;
- Political marginalization in the development of sites in one part of the country;
- The ongoing crisis prevents the development of SHP in the region with a significant SHP potential;
- Corruption;
- Risk of local sabotage of structures.[8,16,19]

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1.2.3

Central African Republic

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Key facts

Population	4,594,620[1]
Area	622,984 km^2
Climate	The climate of the Central African Republic is tropical and includes both a rainy and a dry season. Daily temperature varies between 19 °C and 30 °C during the wet season, from May to October, and could reach from 18 °C to 40 °C in the dry season, from December to April.[2]
Topography	Central African Republic is a landlocked country, with rich, arable soil and important natural resources, such as gold, wood and diamonds.[3] Rolling hills cover the centre and the south of the country. In the southeast there is a dense, tropical forest, while in the north the land becomes more flat, similar to a savanna. Mount Kayagangiri is the highest point in the country, rising at 1,420 metres. The lowest point in Central African Republic is the Oubangui River at 335 metres.[3,4]
Rain pattern	Heavy rainstorms frequently occur during the rainy season. Maximum annual precipitation could reach 1,800 mm. In the Karre Mountains the average rainfall is estimated at 1,500 mm. The north of the country is drier than the south.[2] The average annual precipitation is 1,373 mm.[2,5]
Hydrology	There are important waterways harmoniously distributed across the territory of the Central African Republic. In the north of the country, Chari River tributaries flow. The Ubangi River is one of the most iconic in the country, forming the southern border with Congo. It has numerous tributaries, such as the Chinko, Kotto, Lobaye, Mbari and Ouaka rivers. The Mbomou River or Bomu represents the Ubangi River's headstream, flowing 725 km towards the west and also contributes to forming the border with the Democratic Republic of Congo.[2]

Electricity sector overview

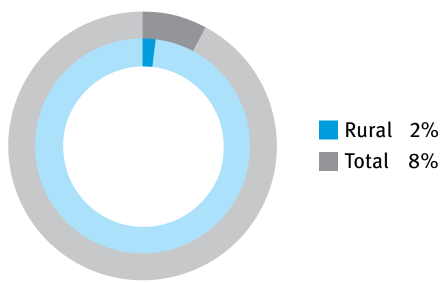
The generation of electricity was estimated at approximately 171 GWh at the end of 2015. Roughly 170 GWh were produced due to hydropower and 1 GWh from thermal plants. Final electricity consumption in the same year was 161 GWh, while 10 GWh were recorded as losses.[6] Figure 1 offers more details on electricity production by source in the Central African Republic. Due to recently approved and commenced sustainable development projects in the country, there is a visible increase in the country's reliance on hydropower for electricity generation.[5]

Figure 1.
Annual electricity generation by source in the Central African Republic (GWh)

Source: UN[6]

According to the World Bank, the country's total installed capacity is 28 MW. Hydropower and diesel generators are the only known sources of electricity in the country. After the 2013 crisis, only three out of 16 district centres still receive electricity from the national power utility, Energie Centralafricaine (ENERCA): Bossangoa, Mobaye and Mongoumba.[7] Total access to electricity in the country is very low, reaching 8 per cent at the end of 2016. The capital city, Bangui, has the highest access to electricity in the Central African Republic, estimated at 35 per cent. Figure 2 offers more information on access to electricity as a percentage of the population.[7]

Figure 2.
Electrification rate in the Central African Republic (%)



Source: WB[7]

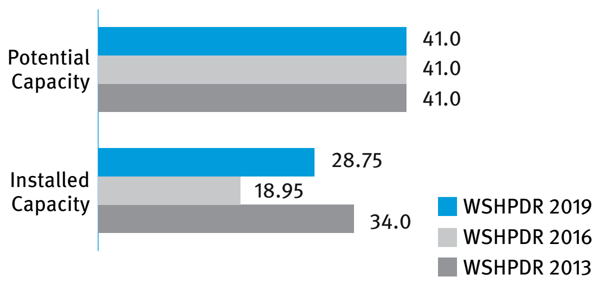
The Ministry of Development for Energy and Water Resources (MDEWR) oversees the electricity sector in the Central African Republic. A Directorate General for Electricity was established as part of the Ministry. Other important institutions are ENERCA, owned by the Government, the Rural Electrification Agency (ACER) and the Autonomous Electricity Sector Regulatory Agency (ARSEC).[7]

The average electricity tariff in 2016 was 0.14 US$/kWh. While the sector is more liberalized at present, ENERCA still manages 100 per cent of the sector operations and investment. The high cost of electricity in the country might be explained by the existent monopoly. Large electricity debts by both private customers and state institutions were recorded at the end of 2016, with the Water Company of the Central African Republic (SODECA) having the highest debt, estimated at US$ 9.2 million.[7] Frequent service interruptions as well as poorly maintained infrastructure and high operation and management costs are part of the issues encountered in the electricity sector. The Water and Electricity Project proposed by the World Bank was approved on 17 January 2018 and is aiming to improve access to electricity and clean-water in the Central African Republic.[7]

Small hydropower sector overview

The small hydropower (SHP) definition in the Central African Republic is the same as the one used in the *World Small Hydropower Development Report (WSHPDR)* and refers to plants of up to 10 MW. The total installed capacity of SHP reached 28.75 MW after the construction of the Boali III plant. Due to recent studies conducted in the region with the approval of the Government of Central African Republic, data available at present is more comprehensive.[8] SHP potential capacity remains 41 MW, as no recent data was made available.[11] However, 30 sites for hydropower development for plants of varying sizes were identified, with a total capacity between 0.5 MW and 180 MW.[10]

Figure 3.
Small hydropower capacities 2013/2016/2019 in the Central African Republic (MW)



Source: UNEP,[8] *WSHPDR 2013*,[9] *WSHPDR 2016*[11]

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

Three SHP plants are installed and in operation at present: Boali I (8.75 MW), Boali II (10 MW) and Boali III (10 MW).[8] According to the existent data, Boali I could have additional or planned capacity of up to 9.5 MW.[14] Therefore, it is expected that installed SHP capacity will increase in the following years. It is believed that off-grid plants as well as multiple micro- and pico-hydropower units also exist, however, there is no data available with regards to the installed capacity or generation potential at the moment.[11] According to the Intended National Determined Contributions (INDCs), the Central African Republic will develop the 60 kW La Kotto hydroelectric plant. Other medium and large hydropower plants will also be developed.[12] Table 1 summarizes the data existent on SHP plants in the country.

Table 1.
Small hydropower plants in the Central African Republic

Plant name	*Installed capacity*	*Location*
Boali I	8.75 MW	E of Vange, Ombella-MPoko
Boali II	10 MW	E of Vange, Ombella-MPoko
Boali III	10 MW	E of Vange, Ombella-MPoko

Source: UNEP[8]

The United Nations Development Programme (UNDP), in collaboration with the Global Environment Facility (GEF), attempted to develop capacity and encourage investment in the Western and Middle Africa regions, including in the Central African Republic, through the implementation of a new project. The project aimed to develop 36 SHP stations in the region, alongside creating a SHP network. As of 2011, the project was cancelled due to regional political instability. In the Central African Republic, there are currently no feed-in tariff schemes for SHP.[13]

Renewable energy policy

In 2015, the Government of the Central African Republic officially declared its intention to support diversified and sustainable development in the country and promote technological innovation, transparency and openness, ensuring uniform progress by 2030. In order to reach its aim, the country agreed to implement the following projects, benefiting from the international support necessary: the construction of a solar power plant at Bangui and the development of a 72 MW hydropower plant at Lobaye and a 180 MW hydropower plant at Dimoli. The development of the Mobaye hydropower plant is also planned in the next 15 years. The recent political transition and post-conflict situation might affect future renewable energy project-development in the country and make the implementation process slower and costlier. However, there is an increased interest in developing renewable energy technology in the Central African Republic. Targeted technologies are mainly micro-hydropower dams and solar panels.[16]

Most renewable energy types, such as solar, wind and geo-thermal, are still widely unexplored in the country. There is existent potential for the geothermal energy, however, no studies were conducted to determine its status. The excess of wind speed was measured at 5 meters per second and, therefore, wind power could also be a viable alternative for electricity generation in the region. The high costs associated with the development of solar energy might limit its use in the Central African Republic to certain applications or services.[17]

Barriers to small hydropower development

There are multiple barriers to SHP development in the country. However, due to its known benefits and potential, there are also considerate efforts made to implement future SHP policies in the Central African Republic. Some of the most important barriers to SHP dissemination are the following:

- The strong monopoly in the electricity sector disincentives investors, increases the project-related costs, and limits potential profit;
- Lack of feed-in tariffs and other support schemes for SHP development;
- Lack of trained staff, able to ensure efficient operation, maintenance and management of SHP facilities;
- Limited financial resources and political unrest might deter future investment in SHP;
- No standards for SHP are developed in the region, which makes current access to electricity from SHP generators unreliable and affects the prospects for future projects.[11,15]

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1.2.4 Congo

International Center on Small Hydro Power (ICSHP)

Key facts

Population	5,260,750 [1]
Area	342,000 km^2
Climate	Congo is characterized by a tropical climate with heavy precipitation, high temperatures and humidity. Temperatures remain rather stable throughout the year with little seasonal variation. Average annual temperatures range between 20 °C and 29 °C. However, in the south, under the impact of the Benguela Current, which flows northwards in the South Atlantic Ocean, temperatures can be as low as 10 °C. Average daily humidity is approximately 80 per cent.[2]
Topography	A 40-kilometre wide coastal plain stretches along the coastal line, and it gradually rises to the low Mayombe Massif. The Massif is followed by the Niari Valley, which in the north rises to the Chaillu Massif at up to 700 metres and in the south to the Cataractes Plateau. Beyond the Niari Valley lies a series of plateaus at approximately 490 metres. A vast plain occupies the north-eastern part of the country. The highest peak is Mont Nabemba (1,020 metres) in the north-west of the country.[2]
Rain pattern	Precipitation is abundant but varies throughout the year and across regions, with the equator crossing the country in half. The north of the country experiences a dry season from November to April and a rainy season from April to November, whereas in the southern part the rainfall pattern is reverse. Annual precipitation averages 1,200 mm but often surpasses 2,000 mm.[2]
Hydrology	The major river is the Congo River. Its main northern tributary, the Ubangi River, flows southwards and forms the country's eastern border. The major southern tributaries of the Congo River include the Sangha, Likouala, Alima, Nkeni, Lefini, Djoue and Foulakari.[2]

Electricity sector overview

The installed capacity of Congo, as of June 2018, was 610 MW. Thermal power accounted for approximately 63 per cent and hydropower for 37 per cent (Figure 1). In addition to its domestic capacity, Congo imports 50 MW from the Inga hydropower plants in the Democratic Republic of the Congo.[3,4]

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

Source: LCA,[3] ANDRITZ HYDRO[4]

Almost half of the country's total installed capacity comes from the gas-fired Congo Power Plant (Centrale Electrique du Congo, CEC) (Table 1). The role of this plant is particularly important during the dry season when generation by hydropower plants decreases.[5] The plant has two turbines, which have operated in parallel with the Inga hydropower plant in the Democratic Republic of the Congo since 2015. The Government is considering the expansion of the plant through the addition of a third turbine, which will bring the total capacity of the plant to 450 MW.[6] After the introduction of the third turbine, the plant might be converted to combined cycle, which will improve the efficiency of the plant. The capacity of the plant can be further increased to 650 MW in the future.[7]

Table 1.
Power plants in Congo

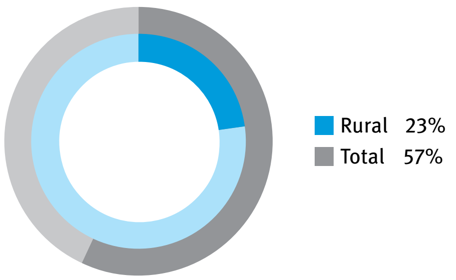
Power plant	*Type*	*Installed capacity (MW)*
CEC Pointe-Noire	Thermal power	300
Brazzaville	Thermal power	32
Djeno	Thermal power	50
Imboulou	Hydropower	120
Moukoukoulou	Hydropower	74
Liouesso	Hydropower	19.2
Djoue	Hydropower	15
Total		**610.2**

Source: LCA,[3] ANDRITZ HYDRO[4]

There are four hydropower plants in the country, however, only three of them are operational. The Djoue hydropower plant has not been functioning since 2007 due to rehabilitation works.[4] The Liouesso hydropower plant, with a capacity of 19.2 MW, was commissioned in the northern Sangha Department on the Sangha River in 2017.[8] The installation of this plant aimed to foster economic activity in the region. Previously, users had access to electricity for only a couple of hours per day.[8]

In 2016, 57 per cent of Congo's population had access to electricity, including 74 per cent in urban areas and 23 per cent in rural areas (Figure 2).[1] The electricity demand of Congo has been growing and is expected to exceed 1,000 MW within the coming decade. In particular, the demand of the Pointe-Noire special economic zone is expected to reach 700 MW, the demand of the city of Brazzaville 250 MW and of the potash mines in Kouilou 150 MW.[10] Therefore, the Government aims to increase the electricity generating capacity of the country.

Figure 2.
Electrification rate in Congo (%)



Source: World Bank[1]

The projects under development include the Chollet hydropower plant, with a capacity of 600 MW, which is to be jointly developed by Cameroon and Congo. The plant will be located in the Ngbala region of Congo on the Dja River and will make part of the Central Africa Power Pool (CAPP). The project envisages the construction of electricity lines between the two countries and will interconnect their electricity networks. Congo will be the major beneficiary of the project, receiving 300 MW of the capacity, Cameroon will receive 60 MW and the remaining 240 MW will go to neighbouring countries. The contract on the construction of the plant was signed in 2010, however, little progress had been made until 2017 when the Intergovernmental Committee of the two countries met to confirm the intention to accelerate the development of the project.[11]

Another potential project is the Sounda hydropower plant located in the Kouilou Department. In November 2017, the results of the feasibility study for the project were presented to the public. The estimated potential of the project is 1,000 MW. The project will be developed as a private-public partnership and is supported by the International Finance Corporation of the World Bank.[9] A number of other potential hydropower projects are currently under consideration.[12]

The electricity sector of Congo is regulated by the Ministry of Energy and Hydraulics, and the National Agency for Rural Electrification (Agence Nationale d'Electrification Rurale, ANER) is in charge of rural electrification. The generation subsector was liberalized in 2003, however, a major role in the electricity market is still being played by the state-owned company the National Electricity Company (Société Nationale d'Electricité, SNE), which was founded in 1967 through Law No. 67. SNE produces, transports, distributes and markets electricity and maintains electrical infrastructure.[13] In February 2018, the Government approved the plan to dissolve the SNE as well as the National Water Distribution Company (Societe Nationale de Distribution d'Eau, SNDE) since they proved to be inefficient and failed to reach sufficient profitability despite state investment. SNE will be replaced with two public limited companies (Société de Patrimoine pour le secteur de l'électricité, SPSE, and La Société de Transport de l'électricité, STE), which will manage the sector based on public service concession contracts between the Government and public and private operators. The reform is expected to attract investment into the sector.[14]

Electricity in Congo is transmitted via 110 kV and 220 kV lines and distributed via 30 kV, 20 kV, 6.6 kV, 380 V and 220 V lines. Following Decree No. 681 of 19 March 1994 by the Ministry of Commerce, Consumption and Small and Medium Enterprises, electricity tariffs in Congo have been unified across the country and divided into three categories: low voltage, public lighting and medium and high voltage. Electricity prices vary depending on these three categories and the level of consumption regardless of the type of consumer. Low voltage tariffs vary between 31.2 FCFA/kWh (0.019 US$/kWh) and 49.08 FCFA/kWh (0.030 US$/kWh).[15]

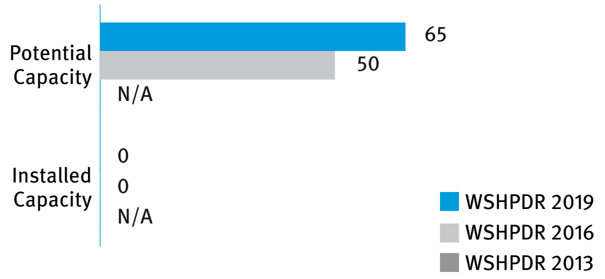
Small hydropower sector overview

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

At present, Congo has four hydropower plants, all of which are classified as large hydropower. The potential for hydropower development is estimated at some 14,000 MW.[16] SHP potential is expected to be rather significant as well, however, no exact and comprehensive estimate is available. The Hydropower Atlas developed by the United Nations Development Programme (UNDP) in 2008 identified 17 potential SHP sites with capacities ranging between 6 kW and 6 MW and a combined capacity of almost 21 MW.[16] Another study identified 10 potential sites with estimated capacities ranging between 5 MW and 10 MW with a combined capacity of approximately 50 MW.[17] Based on these two estimates, the potential of SHP in Congo should be at least 65 MW. Compared to the results of the *World Small Hydropower Development Report (WSHPDR) 2016*, the installed capacity has not changed, whereas the potential capacity increased by 30 per cent due to access to more accurate data (Figure 3).

Although SHP could be used to meet the needs for electricity in rural areas as well as feed into the national grid, serving as an efficient and environmentally sustainable source, the sector has faced numerous barriers hindering its development. The gaps in the regulatory framework in relation to SHP projects, the lack of local skills to install, operate and maintain an SHP plant as well as local technology make the sector less attractive than other power projects.[16] Another major barrier is low electricity tariffs.[17]

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



Source: LCA,[3] *WSHPDR 2016*,[17] *WSHPDR 2013*[18]

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

Renewable energy policy

Besides a significant hydropower potential, Congo also enjoys considerable solar power resources estimated at approximately 5 kWh/m²/day. An assessment of the country's wind resources would also help identify the potential for their commercial exploitation.[16] The Government envisages the development of renewable energy sources available in the country, including hydropower, biomass, solar power and wind power, in particular in remote areas. However, no policy or strategy promoting renewable energy has been developed to date. As a result, the available resources remain untapped.

The major laws and regulations of the electricity sector include:

- Law No. 14/2003 of 10 April 2003, defining the Electricity Code and liberalizing the market;
- Law No. 15/2003 of 10 April 2003, establishing ANER;
- Law No. 16/2003 of 10 April 2003, establishing the Agency for the Regulation of the Electricity Sector;
- Law No. 17/2003 of 10 April 2003, establishing the Development Fund of the Electricity Sector;
- Decree No. 2010-822 of 31 December 2010, approving the development strategy for the sectors of electricity, water and sanitation.

In accordance with the Electricity Act of 2013, independent power producers are required to obtain a licence. However, for small-scale projects of electricity generation, transmission, distribution and sales in rural areas, it suffices to obtain an authorisation by the corresponding Ministry.

Barriers to small hydropower development

The major barriers to SHP development in Congo include:

- Gaps in the legal, regulatory and institutional framework;
- Lack of local skilled workforce to design, install, operate and maintain SHP plants;
- Lack of tax exemptions on SHP equipment;
- Low electricity prices;
- Low awareness of SHP among the population.[16]

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1.2.5

Democratic Republic of the Congo

Camille Augustin Kabasele Dikangala and Roger Limoko, Ministry of Energy and Hydraulic Resources; Lambert Engwanda and Disashi Nyama Lemba, la Direction de l'Electrification Rurale de la Société Nationale d'Electricité (SNEL)

Key facts

Population	89,592,000[1]
Area	2,345,441 km[2]
Climate	The Democratic Republic of the Congo lies on the equator, with one third of the country lying to the north and two-thirds to the south. The climate is hot and humid in the river basin and cool and dry in the southern highlands, with a cold, alpine climate in the Rwenzori Mountains.[2] Average monthly temperatures in Kinshasa are between 23 °C in July to 26 °C in April.[3]
Topography	In the centre of the country lies the large Congo River basin covered by equatorial rainforest. The whole territory is forested, more or less thickly. There are plains and slopes in the west of the country, hills in the north and south and mountains in the east.[2]
Rain pattern	South of the equator, the rainy season lasts from October to May, and north of the equator, from April to November. Along the equator, rainfall is fairly regular throughout the year. During the wet season, thunderstorms are often violent but seldom last more than a few hours. The average rainfall for the entire country is approximately 1,070 mm.[2]
Hydrology	The Congo River is the deepest known river in the world with a discharge of more than 44,000 m^3/sec. The depth of the Congo River exceeds 228 metres at several points during its course.[2] Approximately 44 per cent, or 40,000 MW, of the country's hydropower potential is concentrated at the site of Inga, located at 150 km from the mouth of the Congo River.[4]

Electricity sector overview

In 2016, the installed electricity capacity in the Democratic Republic of the Congo was 2,931 MW, with approximately 2,812 MW coming from hydropower and 119 MW from thermal power (Figure 1).[5] However, due to breakdown and maintenance issues, available capacity was significantly lower, at approximately half of the installed capacity, mostly concentrated around large agglomerations, such as the country capital, provincial capitals and the surrounding areas.[6,7] The electricity demand in the Democratic Republic of the Congo in 2020 is expected to reach 30,889 GWh.[8]

Figure 1.
Installed electricity capacity by source in the Democratic Republic of the Congo (MW)

Source: MEHR[5]

The Ministry of Energy and Hydraulic Resources (MEHR) is responsible for the energy sector, while the Société Nationale d'Électricité (SNEL) is the national utility responsible for generation, transmission and distribution of electricity. The electricity grid and the transmission system have been improved and enhanced over the years. In 1970, the high-voltage (HV) transmission system was 2,475.7 kilometres. In 1982, the total amount of HV transmission in the country had extended to 5,260.7 kilometres. By 2012, the distance serviced by the HV transmission network was 5,788 km.[6,8] In 2015, a second transmission system (400 kV) connecting Inga and Kinshasa and covering a distance of 277.3 km was completed.[6,9] This transmission network was financed by the European Investment Bank in order to reinforce and secure electricity generation for the city of Kinshasa.[6]

There is a significant electricity shortage in the country. The shortage covers both the installed capacity of the country and the available electricity after losses. Several rehabilitation programmes are being carried out by the Government in order to solve this problem. There are three major rehabilitation and construction projects: the Projet du Marché de l'Électricité (PMEDE), the Projet du Marché d'Électricité en Afrique Australe (SAPMP) and the Projet d'électrification périurbaine et rurale (PEPUR). The aforementioned programmes are being financed by the World Bank, the African Development Bank and the

European Investment Bank, with a budget of approximately US$ 1,500 million.[6]

The PMEDE project aims to rehabilitate central plants in Inga, with the purpose of increasing the amount of electricity produced. It also aims to secure and improve electricity efficiency, generation and the electricity grid in the capital of the country. On the other hand, the SAPMP project has the target of increasing the electricity exports of SNEL, mainly for the electricity generated at Inga and sent to South Africa. Selling this electricity has to be done at a price that will allow SNEL to repay debts, maintain installations and develop the interior grid.[6]

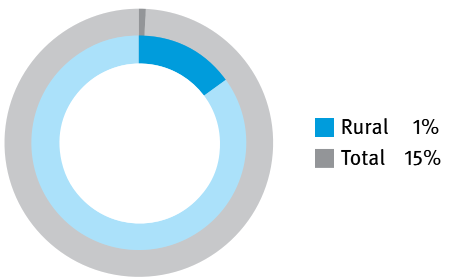
Table 1
Expected increase in electricity demand in the Democratic Republic of Congo (GWh)

Sector	*2015*	*2020*	*2025*	*2030*
Industrial	5,743	9,801	17,141	30,948
Transport	44.7	148.9	242.3	335.6
Household	11,480	18,598	281,556	48,781
Services	1,496.8	2,341.4	3,581.7	5,754.5
Total	**18,764.5**	**30,889.3**	**34,7720.3**	**85,819.1**

Source: MEHR[8]

The total electrification rate in the Democratic Republic of the Congo is approximately 15 per cent, with access to electricity in urban areas at 40.1 per cent and just 1 per cent in rural areas (Figure 2).[10] An increasing proportion of people living in towns use diesel or petrol-powered generators to produce their own electricity. This includes businesses (e.g., mining, logging companies, agro-industries), farmers and religious missions.[6,11] Connecting to the grid is expensive and local firms, most of which are small and informal, wait approximately seven months to get connected.[6,8]

Figure 2.
Electrification rate in the Democratic Republic of the Congo (%)



Source: INS[10]

The consumption of energy and, therefore, the need for electricity generation varies depending on the region. Southern cities in the province of Katanga, such as Lumumbashi, have an installed capacity of approximately 2,000 MW. However, this only satisfies 55 per cent of the electricity demand in the province. The cities of Goma and Bukavu have an installed capacity of 250 MW, which satisfies only 56 per cent of the demand. The city of Matadi has only 51 per cent of the installed capacity that is required to cover its electricity demand.[6,8]

The Government is working on the implementation of a strategy aiming to develop the electricity sector. Among the different policies, the main points of this strategy are the following:

- Development of additional energy sources and, above everything, the installation of the Inga site (approximately 40,000 MW). The development of the Inga site would require significant international investment. Most of the existent plants will also need to be rehabilitated;
- Promotion of cooperation and regional integration by exporting electricity when possible;
- Creation of an authority in charge of regulating the electricity sector and of a national agency in charge of rural electrification. Law No. 14/011 on the Electricity Sector establishes these two institutions and the liberalization of the electricity sector for private operators;
- Reform of the energy administration in order to build up institutional capacities;
- Regarding the promotion of regional energy cooperation, the target is to participate in projects that are already being carried out by regional organizations, such as the Economic Community of African Central States, the Southern African Development Community and the Economic Community of the Great Lake Countries.[6]

The electricity sector is liberalized and some private companies produce and sell electricity to consumers (Société d'Électrification du Nord Kivu, with 2 MW in Butembo, and Électricité du Congo generating 1.56 MW in Tshikapa). There are also some auto-producers who generate electricity for their own use. Nonetheless, SNEL and its facilities, i.e. the State, represent 99 percent of installed capacity. The problem of how to increase the involvement of the private sector in the electricity supply industry is the main concern of the Government. It is hoped that the legal and regulatory framework will soon be defined. The MEHR is in charge of the energy sector and potable water and defines the national energy policy. There is one division within the MEHR that is in charge of rural electrification, which works with the Rural Electrification cell of SNEL.[6,12]

The electricity tariffs in the Democratic Republic of the Congo are set to vary according to voltage, type of consumption and other factors. Prices for low tension consumption by the residential sector vary from 0.027 US$/kWh to 0.087 US$/kWh.[13]

Small hydropower sector overview

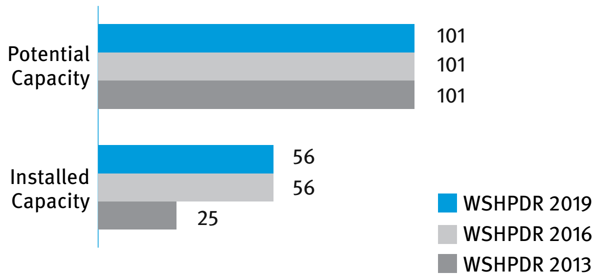
The legislation of the Democratic Republic of the Congo lacks a definition for small hydropower (SHP) plants. However, the country follows international standards and classifications regarding SHP plants, in particular the French norms and standards:

- SHP plants: 500 kW-10 MW;

- Micro-hydropower plants: 20 kW-500 kW;
- Pico-hydropower plants: <20 kW.[6,12]

The SHP installed capacity in the country is approximately 56 MW, of which roughly 6 MW are from plants up to 1 MW.[14] The potential capacity in the Democratic Republic of the Congo is approximately 100.9 MW.[4] It should be noted that the data available for SHP varies by source, and the number of privately owned and operated SHP plants has not been fully identified. Compared to the *World Small Hydropower Development Report (WSHPDR) 2016*, both installed and potential capacity remained unchanged (Figure 3).

Figure 3.
Small hydropower capacities 2013/2016/2019 in the Democratic Republic of the Congo (MW)



Source: IRENA,[4] *WSHPDR 2016*,[6] IRENA,[14] *WSHPDR 2013*[15]

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

The total hydropower installed capacity has increased throughout the years. In 1960, there were 41 sites in total, with a hydropower installed capacity of approximately 690 MW. In 1974, this number increased to 982 MW. Since 1990, capacity has continued to grow, with current capacity reaching 2,812 MW. The total hydropower potential is 100,000 MW (the Inga site alone has a potential of 40,000 MW).[4,6,5]

The plan to promote SHP in the country is included in the national electrification plan. The agency in charge of rural electrification is likely to take over the responsibility of developing SHP. Currently, approximately 100 potential SHP sites have been identified, but more thorough research could double this amount due to the large number of rivers yet to be surveyed.[6,11]

Through the activities of the Sustainable Energy for All (SE4ALL) initiative, with the support of the United Nations Development Programme (UNDP), a mini- and micro-hydropower plant project, the "MCH Project", has been set up for the electrification of rural and peri-urban areas. The project is financed by the Government of the Democratic Republic of the Congo and GEF and has three areas of activity, namely: 1) strengthening the institutional and regulatory framework; 2) pilot investment; and 3) communication and mobilization of funding. It should be noted that three studies have already been carried out and five are in progress.[5]

Renewable energy policy

The Democratic Republic of the Congo does not have a renewable energy policy framework. The electricity sector has been liberalized, however, certain measures have not yet been implemented. The foreseen institutional framework will allow the development of renewable energy policies, for example, with the agency in charge of rural electrification, the Agence Nationale des Services Énergétiques en Milieu Rural et Péri-urbain. Moreover, further financial mechanisms need to be implemented.[6,16]

Barriers to small hydropower development

The Democratic Republic of the Congo is a country with a large amount of hydropower resources. Several important rivers and basins are located within the country, which gives it a hydropower potential of 100,000 MW. However, currently, only a small proportion is operational. The major barriers to SHP development are:

- The poor quality, or complete lack, of equipment;
- Electricity tariffs do not allow for the reimbursement of costs, therefore, the country faces difficulties increasing the financial resources required to invest in the renewable energy sector;
- Some of the foreseen measures (legislative, institutional, financial) have not been implemented.[6]

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1.2.6 Equatorial Guinea

Phillip Stovold, Kaboni Energy Ltd; and International Center on Small Hydro Power (ICSHP)

Key facts

Population	1,267,690[1]
Area	28,052 km^2 [2]
Climate	The climate of Equatorial Guinea is tropical, characterized by wet and dry seasons. Temperature ranges between 16 °C and 33 °C in Malabo, Bioko and the surrounding regions. The highest temperatures in the southern Moka Plateau reach only 21 °C. Rio Muni region has an estimated temperature of 27 °C.[4] The annual average temperature in the country is estimated at 25 °C.[3]
Topography	Narrow coastal plains and mangrove swamps are present in the lower geographical points of Equatorial Guinea. Hills covered by thick forests reach up to1,219 meters and delimit the country's border with Gabon. Pico Basile is the highest point in Equatorial Guinea, measuring 3,008 metres. The peak is located on the volcanic island of Bioko as well as the capital city Malabo.[5]
Rain pattern	The average annual rainfall is estimated at 2,186 mm, according to a data analysis on precipitation conducted between 1901 and 2016. October is the wettest month of the year, with an average rainfall approximated at 380 mm, and July is the driest, with only roughly 50 mm of rain.[6]
Hydrology	The most important rivers in the country are the Mbini, Ntem and Utamboni. The Muni represents the estuary for multiple rivers in Equatorial Guinea, however, it is not a river itself. The Mbini River runs from the east to the west of the country and is known as the Woleu River in Gabon. This river is non-navigable, apart from the first 19 km inland. The Ntem River delimits part of the border with Cameroon. The Utamboni River flows through the south of the country and is the most notable river that has its estuary in the Muni. Mainland Equatorial Guinea rivers also contribute to limited hydroelectric power production.[7]

Electricity sector overview

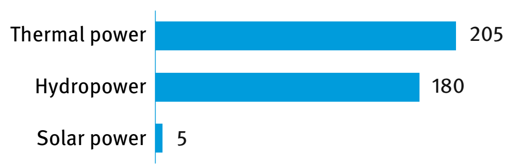
Total generation was at least 1,046 GWh in 2016, higher than the recorded 939 GWh at the end of 2015.[9] Figure 1 offers more detail with regards to the estimated electricity production by source. The recorded losses were approximately 40 GWh. The gross demand for electricity was roughly 899 GWh.[8] The country relies on hydropower to meet the energy demands of its population. Solar energy potential, while low, is considered to be a solution for the future development of the electricity sector. In July 2016, Sociedad de Electricidad de Guinea Ecuatorial (SEGESA) approximated hydropower generation at 650 GWh.

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

Source: UN,[8] SEGESA[9]

As a small governmental business, SEGESA increased its value from US$ 100 million in assets in 2001 to US$ 4 billion in 2016, becoming a very important actor in Equatorial Guinea's electricity market. The company owns a 154 MW gas-fired power station on the island of Bioko and the 120 MW Djibloho hydropower dam. SEGESA is also in charge of the completion and management of the Sendje 200 MW hydropower plant, which will help maintain the uniform production of electricity during the dry season. The Sendje dam was at 60 per cent completion in 2016.[9] The hydropower plant will be in use by 2020. The construction on the dam commenced in 2012 and it includes four Alstom turbines of 50 MW each.[10]

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

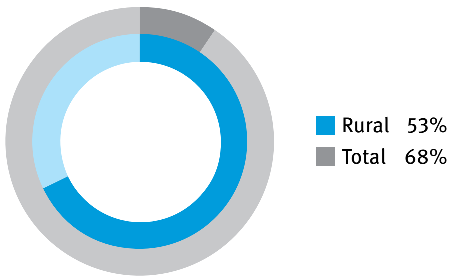


Source: UN[11]

At the end of 2015, the total net installed capacity of the electric power plants was estimated at 390 MW. This statistic also accounts for solar power plants that are not yet in operation and therefore not generating electricity at the present time. After the construction of the 200 MW Sendje project, installed capacity will reach 590 MW.[11] Figure 2 offers more information with regards to the installed capacity by source in Equatorial Guinea. The considerable increase in both thermal and hydropower installed capacity is due to more precise data recently being made available. In addition, following the model of its neighbour, Cameroon, Equatorial Guinea recently implemented new renewable energy projects, commencing with the installation of solar panels.[12]

Access to electricity in the country is still highly unreliable with frequent disruptions in the system. At the end of 2016, only 68 per cent of the population had access to electricity. Progress was made with regards to rural electrification, which has reached roughly 53 per cent. There is no specific data on the electric power transmission and distribution losses in Equatorial Guinea; as a percentage of output, however, the interruptions in service provision are frequent.[14] Figure 3 offers information on the access to electricity as percentage of the population.

Figure 3.
Electrification rate in Equatorial Guinea (%)



Source: WB[14]

Table 1.
Electricity tariffs in Malabo and Bata (US$/kWh)

Energy consumption per month	*Price (US$/kWh)*	*Price (production from diesel, US$/kWh)*
1 – 150 kWh	-	0.11
1 – 250 kWh	0.11	-
151 – 250 kWh	-	0.16
251 – 500 kWh	0.14	0.21
501 – 2,500 kWh	0.18	0.29
2,501 – 5,000 kWh	0.16	0.27
5,001 – 25,000 kWh	0.13	0.25
Above 25,000 kWh	0.11	0.22

Source: SEGESA[13]

The Government of Equatorial Guinea has set prices for enterprises and individuals in accordance with law no. 3/2002. The electricity consumption price varies depending on the location and source of energy. Table 1 only details the tariffs for low voltage users in Malabo and Bata, the major cities in Equatorial Guinea. For the electricity consumption outside of Malabo and Bata, consumers are charged a fixed tariff per kWh. When the supplier is an independent producer, consumers are charged 0.099 US$/kWh. For diesel independent producers the price is 0.14 US$/kWh, while for hydropower independent producers, the set price is 0.11 US$/kWh.[13]

Small hydropower sector overview

Very limited data exist on small hydropower (SHP) in Equatorial Guinea. There is no official definition for SHP, however, for the regional data comparison, the *World Small Hydropower Development Report (WSHPDR)* defines SHP as plants up to 10 MW. There are currently three SHP plants in the country, which correspond to the current definition: the Musola plant has an installed capacity of 0.5 MW, the Riaba SHP plant capacity was estimated at 3.8 MW; and the Bikomo, with 3.2 MW installed capacity. The total installed capacity at present is 7.5 MW.[15] The difference observed between the *WSHPDR 2016* and *2019* installed capacity may be due to the previous lack of data on Musola hydropower plant. There is still no available data on the total potential capacity in Equatorial Guinea. Figure 4 offers more information on the installed capacity data currently available.

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

Source: UNEP,[15] *WSHPDR 2013*,[16] *WSHPDR 2016*[17]

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

The Government of Equatorial Guinea expressed its intention to reform and renovate the three existent SHP plants in the country: the Musola, Riaba and Bikomo. According to SEGESA, rehabilitation of the Riaba and Musola facilities was due for completion in 2016. The Riaba hydroelectric plant was commissioned in July 1989. The Bikomo plant originally had three turbines of 800 kW each and was commissioned in 1981.[18] There are no known plans of future SHP plants construction or of SHP dissemination. The country also has no known feed-in tariffs (FTTs) scheme to benefit SHP electricity producers or construction, operations and maintenance companies.[15]

Renewable energy policy

An Energy Master Plan was initiated by the European Commission to assist developing countries, including Equatorial Guinea, with attracting significant investment in the energy sector, ensuring more effective and sustainable growth. The Technical Assistance Facility (TAF) has a budget of EUR 65 million and the main objectives of the project are to conduct data mining and analysis, country profiling and provide investors with energy sector assessments. Gesto Energy was selected as the company to assist Equatorial Guinea with the evaluation of its energy sector and preparation for the development of an energy roadmap, as part of the European Union Sustainable Energy for All (SE4ALL) TAF project.[19]

Some of the most recent implemented renewable energy projects in Equatorial Guinea are the 5 MW installed capacity Annabon solar micro-grid and the 200 MW hydropower capacity at the Sendje that is under construction. In addition to these projects, the Government of Equatorial Guinea also declared they planned to install an additional hydropower capacity of 400 MW from an auxiliary dam.[18] There are no existent FITs or other green schemes implemented, however the Government of the country expressed its intention to lower tariffs and enhance international and private investment in the sustainable energy sector.[15,18]

Barriers to small hydropower development

There are multiple barriers to SHP development in Equatorial Guinea. Some of the most significant and well-known ones are the following:

- The current primary focus seems to be on implementation of large hydropower projects, such as the Djibloho and Sendje hydropower plants. Apart from the refurbishment plans for existent SHP plants, no other intentions to disseminate SHP in the country has been made official;[18]
- The legislative framework for SHP is imprecise and does not specify details on project development processes as well as formalities for private and international investment in the sector;[17]
- There are no incentive policies in the country for construction, operation and maintenance of SHP plants;[15]
- A lack of training and expertise in SHP technology management and development in the country;
- The lack of a regulatory agency for the energy sector slows down the effective expansion of the country's electricity grid, affects the likelihood of SHP project adoption and deters foreign investment.[20]

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1.2.7 Gabon

Phillip Stovold, Kaboni Energy Ltd; and International Center on Small Hydro Power (ICSHP)

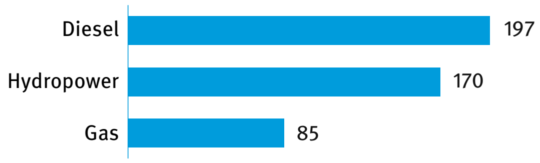
Key facts

Population	2,025,137[1]
Area	267,670 km[2]
Climate	Gabon has an equatorial climate characterized by high temperatures and humidity. Almost all precipitation falls between October and May, whereas the months of June to September see almost no precipitation, although humidity still remains high. Temperatures vary little throughout the year, averaging 25 °C to 27 °C.[2,3]
Topography	The coastal area is represented by a plain ranging in width from 32 km in the south to 160 km in the north. The inland relief is characterized by granite plateaus dissected by rivers and rising to 600 metres above sea level. In the north-west lie the Crystal Mountains, and south of the Ogooué River lies the Chaillu Massif. The highest point is Mount Bengoué at 1,070 metres above sea level, located in the north-east of the country.[2]
Rain pattern	Precipitation ranges from an average of 3,050 mm per year at Libreville to 3,810 mm on the north-western coast.[2]
Hydrology	The main river of Gabon is the Ogooué River, flowing north-westwards before turning westwards and south-westwards. The Ogooué River is the fourth largest river in Africa, with more than 90 per cent of its basin lying within the territory of Gabon. The river collects water from numerous lakes and tributaries. Its major tributary is the Ivindo River, which runs north-eastwards. Before emptying into the Atlantic Ocean south of Port-Gentil, the Ogooué forms a large delta.[4]

Electricity sector overview

The installed capacity of Gabon in 2016 was 452 MW, of which thermal power accounted for 62 per cent and hydropower for 38 per cent (Figure 1). Compared to 2015, the installed capacity increased by almost 6 per cent, with the major contributor to this increase being the introduction of 11 thermal power plants in internal provinces of the country. The installed capacity of hydropower plants in 2016 increased only insignificantly compared to 2015 – by less than 0.06 per cent.[5]

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



Source: SEEG[5]

Electricity generation in Gabon reached 2,329 GWh in 2016, indicating an almost 4 per cent increase compared to the 2,244 GWh in 2015. Conversely, the electricity generation from hydropower decreased by 10 per cent from 918 GWh in 2015 to 821 GWh in 2016 due to poor precipitation. As a result, the share of hydropower in electricity generation decreased from 41 per cent in 2015 to approximately 35 per cent in 2016. On the contrary, the share of thermal power increased from 59 per cent in 2015 to 65 per cent in 2016. Thus, the domination of thermal power in the country's energy mix persisted in 2016 (Figure 2).[5]

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

Source: SEEG[5]

Almost 68 per cent of electricity in 2016 was generated in the Estuaire province, where the country's capital city Libreville is located (Table 1). Electricity consumption in 2016 stood at 1,908 GWh, which was 6 per cent higher than in 2015.[5] In 2016, approximately 91 per cent of the country's population had access to electricity, including nearly 97 per cent in urban areas and 55 per cent in rural areas.[1] In total, 316,168 users were connected to the grid.[5]

In 2016, the electricity network consisted of 4,417 km of distribution lines and 706 km of transmission lines with 2,711 transmission substations. Thus, compared to 2015, the total length of the electricity network in 2016 increased by more than 7 per cent.[5]

Table 1.
Electricity generation and consumption in Gabon by region (GWh)

Region	*Generation*	*Consumption*
Estuaire	1,581.5	1,314.1
Ogooué Maritime	322.2	254.7
Haut-Ogooué - Ogooué-Lolo	260.9	201.6
Woleu-Ntem - Ogooué-Lolo	67.1	59.0
Ngounié - Nyanga	61.0	47.3
Moyen-Ogooué	36.7	31.7
Total	**2,329.4**	**1,908.4**

Source: SEEG[5]

Note: Data is from 2016.

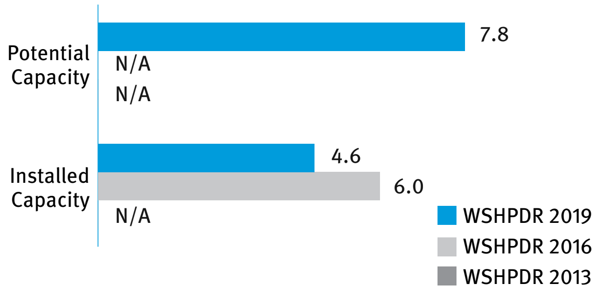
The energy sector of Gabon is regulated by the Ministry of Petroleum and Hydrocarbons and the Ministry of Water and Energy.[6,7] The electricity sector is operated by the Energy and Water Company of Gabon (*Societe d'Energie et d'Eau du Gabo*n, SEEG), which was privatized in 1997 and received a 20-year concession to operate electricity and water services throughout the country. SEEG is currently 51 per cent owned by the French company Veolia and 49 per cent by the Government of Gabon and Gabonese investors.[8] However, in February 2018, the Ministry of Water and Energy temporarily requisitioned SEEG and announced the intention to terminate the contract due to the deteriorated quality of services provided by the company.[9]

Electricity tariffs are set by SEEG based on a concession agreement with the Government. Tariffs are updated three times per year for each of the categories of consumption: 1) single-phase low voltage, 2) three-phase low voltage, and 3) medium voltage. Tariffs increase proportionally to the voltage for both single- and three-phase low voltage consumers. However, for three-phase consumers, the tariff also includes a base rate and varies depending on the period of utilization during the day. For medium voltage, the price also varies according to the region, whereas low-voltage tariffs are uniform across the country.[5,10] In 2018, single-phase low voltage tariffs ranged from 53.21 FCFA/kWh (0.095 US$/kWh) to 142.51 FCFA/kWh (0.250 US$/kWh) and three-phase low voltage tariffs ranged from 83.43 FCFA/kWh (0.150 US$/kWh) to 103.39 FCFA/kWh (0.180 US$/kWh).[16]

Small hydropower sector overview

There is no official definition of small hydropower (SHP) in Gabon, therefore, this report uses the standard definition of up to 10 MW. Gabon has three SHP plants with a total capacity of 4.58 MW (Table 2).[5] The total potential of SHP is unknown, however, based on planned projects, it is possible to conclude that there is at least 7.84 MW of available potential.[5,11] Compared to the *World Small Hydropower Development Report (WSHPDR) 2016*, installed capacity decreased by 1.4 MW, or 23 per cent. This is due to a decrease in the installed capacity of the Bongolo hydropower plant caused by renovation works (Figure 3).[5]

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



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

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

As of the end of 2016, there were six hydropower plants operating in Gabon, of which three were SHP plants (Table 2). The total potential of hydropower in Gabon is estimated to be up to 8,000 MW. Sixty potential sites have been identified, of which 52 were documented, with a maximum capacity up to 7,002 MW, a guaranteed capacity of 5,793 MW and an annual generation of 42,000 GWh.[3] While there is no information on the potential of SHP available, there are at least two SHP projects – Iboundju, with a capacity of 0.4 MW, and Malinga, with a capacity of 1.4 MW. Other hydropower projects under planning or construction include: Ngoulmendjim (115 MW), Empress Falls (84 MW), FE2 Falls (36 MW) and Dibwangui (15 MW).[11,12] Hydropower plants are seen as an integral part of the Government's vision for the development of Gabon.[12]

Table 2.
Hydropower plants in Gabon (MW)

Plant	*Installed capacity*			
	2013	*2014*	*2015*	*2016*
Tchimbele	68.40	68.40	68.40	68.40
Kinguele	57.60	57.60	57.60	57.60
Poubara	38.00	38.00	38.00	39.36
Bongolo	5.46	5.46	5.46	4.00
Mbigou	0.38	0.38	0.38	0.38
Medouneu	0.20	0.20	0.20	0.20
Total	**169.84**	**169.84**	**169.84**	**169.94**

Source: SEEG[5]

Renewable energy policy

There is no comprehensive energy framework or renewable energy law in Gabon. The current national energy policy is reflected in the Emerging Gabon Strategic Plan (Plan Strategique Gabon Emergent, PSGE). PSGE set the goal to increase the country's capacity to 1,200 MW by 2020 in order to meet the demand of the population while ensuring competitiveness, sustainability and the creation of jobs. In particular, PSGE set the goal to increase the share of renewable energy in the country's energy mix from 40 per cent in 2010 to 80 per cent in 2020. This goal is to be achieved predominantly through the development of hydropower. However, the plan also stresses the importance of promoting other renewable energy sources, including biofuels. Other energy-related goals outlined in PSGE include:

- Improvement of energy efficiency in public administration buildings;
- Use of renewable energy and light-emitting diodes (LED) lamps for street lighting;
- Use of renewable and lasting materials in construction to decrease energy consumption.[13]

Hydropower development in Gabon is influenced by Law no. 007/2014, *On the Protection of the Environment*, which stresses the importance of the sustainable use of the country's natural resources, including water. According to the Law, every project that can have a potential effect on the environment is required to submit an Environmental Impact Assessment to the ministry in charge of the environmental issues.[14] In 2012, through Law no. 005/2012, the Gabonese Strategic Investment Fund was established, the aim of which is to assist the development of new industries capable of generating enough revenue to replace decreasing revenues from the fossil fuels sector.[15]

Barriers to small hydropower development

The principal barriers hindering the development of SHP in Gabon include:

- Lack of local expertise;
- Lack of a regulatory and political framework;
- Inadequate energy, water and transportation infrastructure;
- High levels of bureaucracy;
- Poor quality of state services;
- Relatively high labour costs.[3]

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1.2.8

Sao Tome and Principe

Leonel Wagner Neto, Association for Promotion of Renewable Energy and Sustainable Environment; Edchilson Cravid - Directorate General of Natural Resources and Energy; and Adelino Sousa Pontes, Water Supply and Electricity Company of Sao Tome and Principe

Key facts

Population	199,910[1]
Area	1,001 km²
Climate	The climate is tropical and humid in Sao Tome and Principe, with one rainy season lasting from September to May and one dry season lasting from June to August. The average temperature is 21.3 °C.[2]
Topography	Sao Tome and Principe is an archipelago consisting of two small islands and a few islets of volcanic origin and located in the Gulf of Guinea, approximately 300 kilometres west of the African coast, near the equator. The mountains predominantly have a north to south or north-west to south-east orientation. The highest point, Pico de Sao Tome, reaches 2,024 metres and is located in the western part of Sao Tome Island. This part of the island is characterized by vertical slopes and a relatively small coastal area. On the northern and eastern sides of the island, the slopes are more gradual and the coastal area is wider. In the north of Principe Island elevations range between 120 and 180 metres, while the southern side is more inclined, with the highest point being Pico de Principe at 948 metres.[3]
Rain pattern	Precipitation is distributed unevenly and decreases gradually from south to north. Average annual precipitation on the island of Sao Tome is 2,716 mm and on Principe it is 2,293 mm. The area of Sao Tome that receives the most precipitation is located in the valleys of Quija and Xufexufe, where average annual rainfall exceeds 6,000 mm. The area in Principe that receives most precipitation is located close to Pico do Principe and receives an average annual rainfall of 5,000 mm.[4]
Hydrology	The hydrographic network of the country consists of 223 rivers and streams with an average length of 5 to 27 kilometres and waterfalls varying in length between 100 and 800 metres. The main rivers are fast and flow by the deep valleys. There are also numerous streams that cause large-scale erosion during floods. The availability of surface water resources is estimated at 2,026 million m³ per year, of which only 25 per cent can be easily used for drinking, irrigation, industrial use and hydropower generation. The remaining 75 per cent constitutes rapid flows during floods that go directly to the sea because of the steep topography of the country and cause short-term but strong floods in estuarial areas.[5]

Electricity sector overview

Electricity generation in Sao Tome and Principe in 2016 reached 95.3 GWh from thermal power plants and 5.8 GWh from hydropower plants, for a total of 101 GWh (Figure 1).[6] Thus, electricity generation in 2016 was 8.5 per cent higher compared to the 93.1 GWh generated in the previous year. Most of the electricity (95.6 per cent) was generated by publicly-owned power plants and the remaining 4.4 per cent by private power plants. In 2016, there was a decrease of 12.7 per cent in the production of hydropower, which was due to poor hydrological conditions.[6]

Fossil fuels, which are all imported, account for 57 per cent of primary energy consumption, whereas biomass and hydropower account for 42 per cent and 1 per cent, respectively.[7] The use of bioenergy, particularly biomass (firewood and charcoal) for the production of heat or fire, remains the major source of energy for the majority of the population, particularly in rural areas. The energy sector is the largest source of greenhouse gas emissions in the country, contributing 80 per cent of total emissions, while the remaining 20 per cent is represented by the agricultural sector, waste, land use and forestry.[7]

Figure 1.
Annual electricity generation by source in Sao Tome and Principe (GWh)

Source: EMAE[6]

The total capacity of Sao Tome and Principe in 2016 was 32.24 MW, which included 28.08 MW of grid-connected thermal and hydropower plants in Sao Tome, 3.6 MW in Principe and 0.56 MW of off-grid capacity (Table 1).[6] Compared to the *World Small Hydropower Development Report (WSHPDR) 2016*, the country's total installed capacity decreased as a result of the aging of thermal (diesel) power plants. At the same time, new power plants were commissioned, including the thermal plant St. Amaro II and the thermal plant in Porto Alegre.[8]

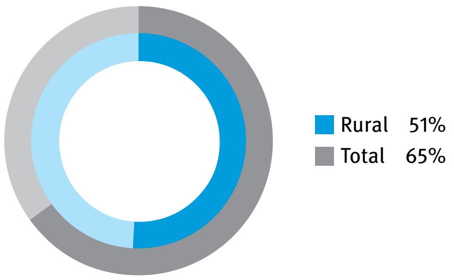
Table 1.
Installed and available capacity in Sao Tome and Principe

	Installed capacity (MW)	*Available capacity (MW)*
Sao Tome	28.08	16.00
Principe	3.60	1.60
Off-grid	0.56	0.43
Total	**32.24**	**18.03**

Source: EMAE[6]

In 2016, 65 per cent of the population had access to electricity, including 73 per cent in urban areas and 51 per cent in rural areas (Figure 2).[1] Consumption of electricity was predominantly concentrated in the capital city and the surrounding area. In 2016, there were 40,775 electricity consumers in the entire country, with 37,169 being residential consumers (91.2 per cent), 2,955 non-residential consumers (7.2 per cent) and 651 delivery points in the public sector (1.6 per cent).[10] Electricity demand in the country is expected to grow, both from the side of industry and the rural and urban populations. Several projects to modernize the electricity sector have been launched with financial support from external partners, including the World Bank, the European Union and the African Development Bank.

Figure 2.
Electrification rate in Sao Tome and Principe (%)



Source: World Bank[1]

With the support of international donors, the Government has made efforts to improve and extend the transmission and distribution network at medium and low voltage (30 kV and 0.4 kV); construct new substations, transformation posts and a new national dispatch centre based on smart technologies; and train technicians in order to adapt to the new quantitative and qualitative technological requirements of the public electricity service.[6] In 2016 and 2017, transmission and distribution lines were rehabilitated and extended to the north and north-east to Santa Catarina Island and to the south of the island of Sao Tome as far as Sao Joao dos Angolares, as well as to Monta Alegre and Praia Burra in the island of Principe. These measures helped increase access to electricity and minimize both technical and financial losses.[10]

Medium voltage transmission and distribution lines in Sao Tome and Principe, both underground and overhead, use the voltages of 6 kV and 30 kV. The total length of lines in Sao Tome is 149,159 km, with 1,167 posts, and 25,156 km, with 305 posts, in Principe.[10]

The Sao Tome and Principe 2030 Transformation Agenda set out the Government's goals to pursue sustainable development, provide access to energy as an essential public good to the entire population; preserve the environment by designing projects that minimize negative environmental impacts and creating favorable conditions for the implementation of relevant environmentally friendly solutions; and promote public-private partnerships with companies that have financial capital, technologies and human resources in the field of renewable energy.[9]

The electricity market was liberalized through Decree No. 26/2014 of 31 December 2014, which set out the autonomy of the electricity production subsector, while maintaining regulation of the transport, distribution and sales subsectors regarding the electricity fed into the national grid.[13] The World Bank is providing support to the Ministry of Infrastructure and Natural Resources with the preparation of a minimum cost energy development plan, which will set out a roadmap for investment in new generation capacities and meeting the growing demand.[11]

In 2017, the Government launched a plan for the development of the energy sector, announcing the following measures and targets:

- Develop an Energy Master Plan;
- Guarantee the availability of electricity corresponding to the growing demand in the 2030 horizon;
- Restructure the sector;
- Ensure a 50 per cent share of renewable energy sources in the national energy mix by 2030;
- Create legal conditions for the implementation of renewable energy sources;
- Rationalize the planned interventions to encourage investments in the sector.[12]

Table 2.
Electricity tariffs in Sao Tome and Principe

Type of consumers	*Tariffs (EUR/kWh (US$/kWh))*
Estimate without a counter	0.793 (0.95)
<100 kWh	0.681 (0.81)
<300 kWh	1.001 (1.20)
> 300 kWh	1.568 (1.87)
Government, municipalities	4.028 (4.81)
Public companies	2.459 (2.94)
Industry	1.400 (1.67)
Businesses	1.568 (1.87)
Embassies, international organizations	2.868 (3.42)

Source: EMAE[10]

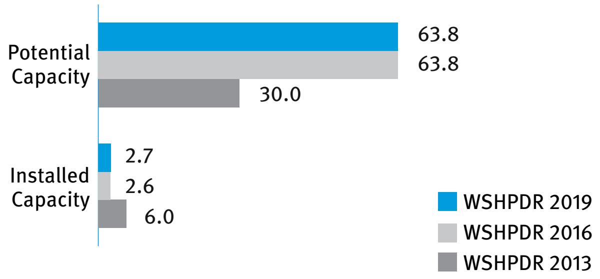
Electricity tariffs are set by the concession holder of the national electricity grid, the National Company of Water and Electricity (EMAE). Tariffs vary depending on the category and volume of consumption and are not differentiated by region due to the uneven distribution of the population across the country (Table 2).

Small hydropower sector overview

Small hydropower (SHP) is defined as power plants up to 10 MW, with a further breakdown into mini-hydropower (101 kW – 1 MW) and micro-hydropower (1 kW – 100 kW).

There is a considerable potential for the development of hydropower resources in Sao Tome and Principe. The current installed capacity is only 2.7 MW, with an additional potential identified at 63.8 MW.[10,14,15] Compared to the results of the *WSHPDR 2016*, installed capacity increased by 4 per cent, while potential capacity has not changed (Figure 3). The increase in installed capacity is due to access to more accurate data.

Figure 3.
Small hydropower capacities 2013/2016/2019 in Sao Tome and Principe (MW)



Source: EMAE,[10] Hidrorumo,[14] CECI,[15] *WSHPDR 2013*,[16] *WSHPDR 2016*[17]

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

There are four hydropower plants on the islands of Sao Tome and Principe: Guégué, Contador and Agostinho Neto are located in Sao Tome and Papagaio is located on Principe. The Guégué, Papagaio and Agostinho Neto power plants belong to the Sao Tome and Principe Hydroelectric Company, which is 60 per cent owned by private companies and 40 per cent by the Government through the EMAE. In terms of installed capacities, Contador is classified as an SHP plant, Guégué as a mini-hydropower plant and Papagaio and Agostinho Neto are micro-hydropower plants (Table 3). [10]

The studies of undeveloped SHP potential in Sao Tome and Principe conducted by Hidrorumo (1996) and updated by CECI Engineering, Consultants, Inc. (2008) identified 34 potential sites.[14,15] Of these, 31 sites are located along eight main rivers in Sao Tome and three sites on three waterways in Principe. The total installed capacity estimated for these 34 sites is 61.068 MW, with a total annual electricity generation of 244,356 MWh, which is more than twice as high as the country's total annual electricity generation in 2016. Of the identified sites, 14 range in capacity between 0.044 MW and 3.75 MW and, with a combined capacity of 31.41 MW, are considered for short-term development.

Table 3.
Small hydropower plants in Sao Tome and Principe

Plant name	*River*	*Installed capacity (MW)*	*Need of refurbishment*	*Connection to the grid*
Contador	Contador	2 x 0.96	Yes, ongoing	On-grid
Guégué	Manuel Jorge	1 x 0.32	Yes	On-grid
Agostinho Neto	Do Ouro	1 x 0.307, 1 x 0.037	Yes	Off-grid
Papagaio	Papagaio	1 x 0.128	Yes	On-grid
Total		**2.712**		

Source: EMAE10

With the support of the United Nations Development Programme, the project for the Promotion of Climate Resistant and Environmentally Sustainable Grid / Isolated Grid of Hydropower Electricity is being carried out in Sao Tome and Principe.[18] The project aims to develop a sustainable isolated grid based on small, mini- and micro- hydropower plants. A set of activities is underway with the objective of removing both technical and institutional barriers, including:

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

Development of regulations for the electricity sector include:

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

In parallel, another project is being financed by the World Bank and the European Bank for Reconstruction and Development to modernize and increase the productive capacity of the Rio Contador hydropower plant, which is expected to increase from the current 2 MW to approximately 4 MW and help decrease the use of fossil fuels in the country by approximately 10 per cent. Coordination of this project is being carried out by the Project Management Fiduciary Agency (AFAP) in partnership with the Department of Forests, Environment, Agriculture, Geographical and Cadastral Services, the General Directorate of Natural Resources and Energy (DGRNE), EMAE and the General Regulatory Authority (AGER).[18]

Available funds for SHP development in Sao Tome and Principe include:

- World Bank – US$ 16 million;
- European Bank for Reconstruction and Development – US$ 13 million;

- African Development Bank – EUR 251,767.78 (US$ 301,556.12);
- Government of Portugal – EUR 3.8 million (US$ 4.6 million) loan.[18]

Renewable energy policy

Policy development, expansion and improvement of the energy sector, customer services and public services delivery all fall within the Government's priorities. The Government has mobilized resources to restructure the energy sector in order to create a more attractive investment environment, particularly for private investment in renewable energy infrastructure. The target was set at a 50 per cent share of renewable energy sources in the country's energy mix by 2030.[12] Ongoing programmes being carried out with the support of development partners are the main line of action.[12] At present, no incentives or financial mechanism exist to support the development of renewable energy sources, including SHP. However, regulations on renewable energy and SHP plants specifically are being drafted with the support of national and international consultancies.

Barriers to small hydropower development

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

The major barriers to SHP development in Sao Tome and Principe include:
- Institutional constraints due to the lack of a national strategy for the hydropower subsector specifically as well as other renewable energy sources;
- Lack of an Electricity Master Plan;
- Lack of legislation and adequate implementation of the recommendations of the 2008 study by CECI Engineering Consultants, Inc.;
- Lack of funding for small, mini- and micro-hydropower projects.

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1.3 Northern Africa

Pirran Driver, Nippon Koei LAC Tunisia

Introduction to the region

The Northern Africa region, as defined by the United Nations Statistics Division, comprises Algeria, Egypt, Libya, Morocco, Sudan, Tunisia, and Western Sahara. With the exception of the westernmost and easternmost countries, the countries of the region have broadly similar climatic conditions, with the northern coastal strip enjoying a Mediterranean climate, giving way to more arid conditions and then desert further south. Additionally, the Atlas mountain range runs across Morocco, Algeria and Tunisia, which causes cooler temperatures and increased precipitation. Sudan has a hot desert climate in the north and an equatorial climate in the south.

This report focuses on five countries of the region, namely: Algeria, Egypt, Morocco, Sudan, and Tunisia. An overview of these countries is given in Table 1. Most of the countries in the region enjoy high levels (99-100 per cent) of electrification; only Sudan has a low electrification rate of 38.5 per cent, more commonly encountered in Sub-Saharan countries. Algeria and Sudan have significant hydrocarbon resources and are largely energy self-sufficient. Egypt also has significant hydrocarbon resources, yet it has been a net energy importer for a number of years. Tunisia has some minor gas and oil resources, but remains a net importer. Morocco has no known exploitable hydrocarbon resources.[4,5]

Table 1.
Overview of countries in Northern Africa

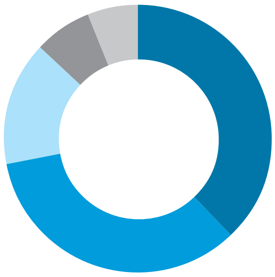
Country	*Total population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Algeria	42.2	28	99	17,140	60,000	269	1,080
Egypt	88.5	57	100	32,015	168,050	2,800	13,352
Morocco	35.1	38	99	8,253	30,715	1,770	1,662
Sudan	39.6	66	39	3,400	14,871	1,593	N/A
Tunisia	11.4	31	100	5,476	18,256	62	45
Total	**216.8**	-	-	**66,284**	**291,892**	**6,494**	**16,139**

Source: *WSHPDR 2019,*[3] WB,[6] WB,[7] STEG[8]

The lack of sufficient hydrocarbon resources and the desire to diversify the energy mix has led the governments in the region to seek alternative energy sources. However, the focus in recent years has favoured the development of wind and solar power over hydropower. Unfortunately, conditions in the region as a whole are not presently conducive to significant small hydropower development.

Algeria and Morocco together account for more than 70 per cent of the region's SHP installed capacity (Figure 1). The total installed small hydropower capacity of the region is reported to be 111.5 MW, which implies that there has been no change compared to the *World Small Hydropower Development Report (WSHPDR) 2016* (Figure 3).

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



Source: *WSHPDR 2019*[3]

Small hydropower definition

Of the countries in the region, Egypt and Tunisia have no formal definition of small hydropower (Table 2). Algeria and Morocco formally adopted the 10 MW threshold for SHP, but they use different limits for the subcategories of pico-, micro-, mini- and small hydropower. Sudan considers small hydropower to be between 500 kW and 5 MW, mini-hydropower from 50 kW to 500 kW and micro-hydropower less than 50 kW. For the purposes of this report the standard definition of the International Center on Small Hydro Power (ICSHP) of up to 10 MW has been applied.

Regional small hydropower overview and renewable energy policy

All five countries of the region covered in this report are host to small hydropower plants. However, hydropower accounts for less than 10 per cent of the combined installed electricity capacity of these countries. Sudan has the highest share of hydropower in its energy mix at 47 per cent of total installed capacity, while small hydropower accounts for a mere 0.2 per cent of its total installed capacity. Morocco also has a high share of hydropower at 21 per cent of total installed capacity, with small hydropower accounting for just 0.5 per cent of total capacity.

Although there are several major rivers suitable for large hydropower, the Nile being a prime example, there is a significant lack of smaller perennial rivers and other water sources suitable for the development of small hydropower. Nonetheless, only 21.5 per cent of the known SHP potential in the covered countries has been developed (Figure 2).

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

Overall, there has been no change in the small hydropower sector in the Northern Africa region since the *WSHPDR 2016*, and little change when compared with the *WSHPDR 2013* (Figure 3). It should be noted that, compared with the *WSHPDR 2013*, the installed small hydropower capacity in the region has decreased by approximately 2 per cent. Similarly, little progress has been observed on a policy level in the region since 2013.

In 2014, **Algeria** formally renounced any future hydropower developments. The country plans to convert the usage of existing hydropower plants away from power generation and towards water supply. Currently, the installed capacity of SHP plants in Algeria remains at 42.1 MW.

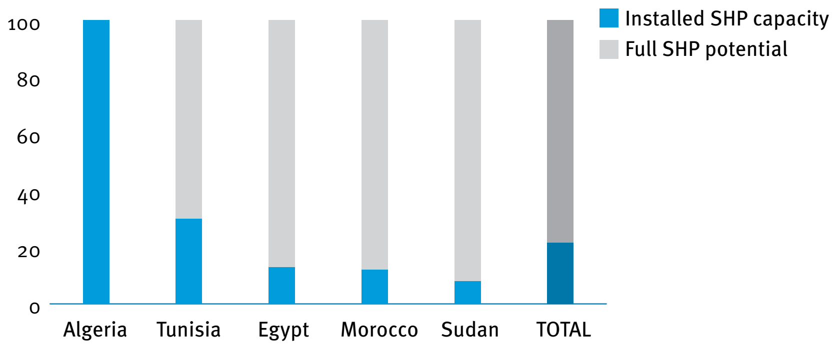
Table 2.
Small hydropower capacities in Northern Africa (local and ICSHP definition) (MW)

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed (<10 MW)*	*Potential (<10 MW)*
Algeria	up to 10	42.1	42.1*	42.1	42.1*
Egypt	-	-	-	6.8	51.7
Morocco	up to 10	38.4	306.6	38.4	306.6
Sudan	up to 5	7.2	63.2	7.2**	63.2**
Tunisia	-	-	-	17.0	56.0
Total		**-**	**-**	**112**	**520**

Source: *WSHPDR 2019* [3]

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

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



Source: *WSHPDR 2019*[3]

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

The installed capacity of SHP in **Egypt** has remained unchanged as well, with four plants with a combined capacity of 6.8 MW currently in operation. Only approximately 13 per cent of the country's known potential has been developed. A further three plants are planned for development and 26 potential sites have been identified.

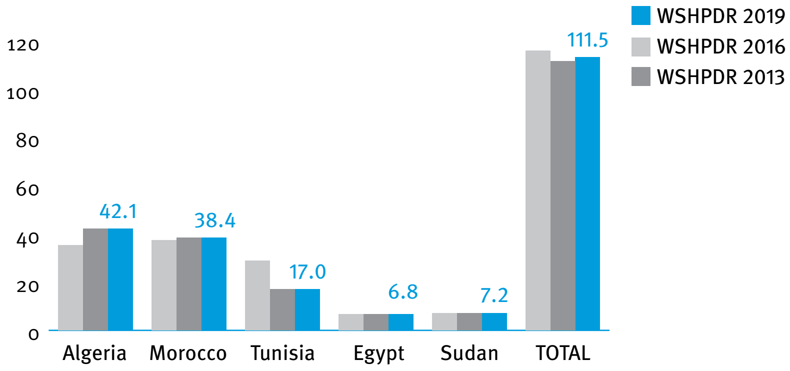
Morocco, the sole country in the region without substantial oil reserves, is also the sole country in the region with any meaningful policy for the development of small hydropower. Since 2010 it has been embarking on a programme for identification and development of micro-hydropower. Morocco has recently identified 125 new sites suitable for small or micro-hydropower plants, with a total potential capacity estimated at 306.6 MW. The country's current SHP installed capacity remains at 38.4 MW.

Sudan is the principal country in the region that is currently engaged in significant hydropower development, but it continues to focus on larger schemes. Currently, Sudan has a single hydropower plant with a capacity of 7.2 MW, while the total potential is estimated to be at least 63.2 MW.

The total installed capacity of SHP in **Tunisia** is 17 MW. It comes from five plants, and has remained unchanged since the *WSHPDR 2016*. Potential capacity is estimated to be 56 MW. However, there is little interest in hydropower from neither the Government nor private investors. Therefore, no significant development in the sector can be currently expected.

Currently no country in the region has a **feed-in-tariff (FIT)** scheme covering SHP. In 2014, Algeria and Egypt introduced FITs, but neither include hydropower. The Government of Sudan, with the support of the United Nations Development Programme (UNDP), is developing a FIT programme to encourage renewable energy projects, both grid-connected and off-grid, which might also include SHP.

Figure 3.
Change in installed capacity of SHP from *WSHPDR 2013* to *2019* by country in Northern Africa (MW)



Source: *WSHPDR 2013*,[1] *WSHPDR 2016*,[2] *WSHPDR 2019*[3]
Note: *WSHPDR* stands for *World Small Hydropower Development Report*. For all countries, data is for SHP up to 10 MW.

Barriers to small hydropower development

Although the countries of the region generally have high economic burdens resulting from extensive energy subsidies, there is a general lack of interest from governments in developing the hydropower sector, and specifically small hydropower. The governments are instead seeking to facilitate investments in nuclear, solar and wind power as more viable means through which to achieve their generally ambitious alternative energy expansion plans. With the exception of **Morocco** and **Sudan**, there is little indication that policymakers have small hydropower on their agendas. Furthermore, the Government of **Algeria** renounced the production of electricity from dams and decided to close hydropower plants in the country.

In addition to the aforementioned barriers, in **Egypt** the lack of interest in SHP stems from the consensus that most of the Nile River has been developed. However, this assessment is largely based on large hydropower projects. Should more accurate studies on SHP potential be undertaken, it may emerge that a significant undeveloped potential still exists.

In **Morocco** and **Sudan**, SHP development is also hindered by a lack of awareness among the population about its benefits, limited policy commitments and limited commitments from civil society, as well as a lack of interest from research institutes to undertake research and development projects on SHP. Other key factors in the case of Sudan include low levels of individual income, limited regulation of technical specifications, particularly for grid connection, and a lack of expertise in the renewable energy sector.

Tunisia experiences difficulties with access to hydropower technologies and has a limited infrastructure for manufacturing, installation and operation of hydropower equipment. There is also a lack of local expertise to undertake feasibility studies.

As little has changed in the past three years in the Northern Africa Region, the final message of this introduction remains much the same as it was in the *WSHPDR 2016*: it is hoped that in the coming years the governments in the region will become more interested in small hydropower development. Whilst solar and wind technologies undoubtedly offer the large capacity gains that the regional governments currently seek, small hydropower offers a unique proposition of low cost renewable energy without the high land usage, landscape damage and other negative impacts that are commonly associated with solar and wind power, and would offer the governments in the region a more balanced spread of energy investments.

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1.3.1 Algeria

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Key facts

Population	42,200,000 [1]
Area	2,381,741 km² [2]
Climate	In Algeria, there are three types of climate: the mild Mediterranean climate of the coast (zone 1), the transitional climate of the northern hills and mountains (zone 2), which is more continental and moderately rainy; and finally, the desert climate of the vast area occupied by the Sahara (zone 3). In the thin coastal strip, the climate is typically Mediterranean, with mild, rainy winters and hot, sunny summers. The temperatures on the coast are rather uniform; the temperature in January is between 11 °C and 12 °C, whilst in August it can reach between 25 °C and 36 °C. In the vast Algerian desert, the climate is characterized by aridity and heat during the long summer months. It becomes progressively hotter and drier as you go south. Daytime temperatures in the desert can vary between 28 °C and 49 °C.[3]
Topography	The parallel mountain ranges of the Tell or Maritime Atlas and the Saharan Atlas divide Algeria into three basic longitudinal zones, running generally from East to West: the Mediterranean zone or Tell, the High Plateaus and the Sahara Desert, which alone accounts for at least 80 per cent of Algeria's total land area. About half of Algeria is 900 metres or more above sea level and about 70 per cent of the area is between 760 and 1,680 metres in elevation. The highest point is Mount Tahat (3,003 m), in the Ahaggar Range of the Sahara.[2,4] Algeria lies on the African Tectonic Plate. North-western Algeria is a seismologically active area.[5]
Rain pattern	In the thin coastal strip, the climate is typically Mediterranean, with mild, rainy winters and hot, sunny summers. The landscape in the western part is more arid due to scarcer rains that fluctuate between 330 and 400 millimetres per year. Rainfall becomes more abundant in the centre and east of Algeria, where it fluctuates between 600 and 800 millimetres. Most rainfall occurs between October and April. In the desert region the precipitation is sparse and irregular. Annual rainfall is 100 billion m³, of which 80 per cent evaporates into the atmosphere.
Hydrology	Algeria has numerous rivers, most of which have short courses. The Chelif River, located between the Atlas Mountains and the Mediterranean Sea, is the longest and most important river of Algeria (725 km). It has an irregular flow, with the longest continuous one being from November to March. The Djedi River is 479.6 km in length, making it the second longest in Algeria. Similar to the Chelif, it begins in the Saharan Atlas Mountains at around 1,402 metres in elevation. The Djedi empties into lake Chott Melrhir, which is located at 39.6 metres below sea level, the lowest point in Algeria. Other major rivers in Algeria include the Medjerda (450.6 km), Ziz (281.6 km) and Seybouse (225.3 km).[6]

Electricity sector overview

The total electricity installed generating capacity in Algeria is 17.12 GW (2016 est.). According to 2016 estimates, the country produces 60,000 GWh of electricity and consumes 59,000 GWh. Algeria exports 900 GWh electricity and imports 736 GWh (2014 est.). There is no electricity generated through nuclear energy in the country.[8,11]

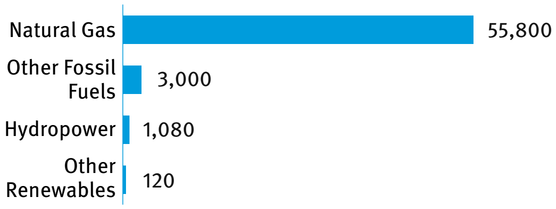
Algeria's energy mix is almost exclusively based on fossil fuels, using natural gas to generate electricity due to its availability and low cost. In addition, Algeria also enjoys a large renewable energy (RE) potential from solar, wind, geothermal and biomass, which the Government is trying to harness by launching an ambitious RE and Energy Efficiency (EE) Programme (February 2011). Moreover, the revolution in RE, in terms of technological development and costs, and the fostering of decentralized RE projects may help reduce the consumption of fossil fuels and ensure reserves for future generations. Algeria has thus set itself a target of achieving a national energy balance with a 27 per cent share of RE by 2030. The share of RE power by 2023 will represent about 17 per cent of installed capacity (5,539 MW) compared to 4.74 per cent in 2011 (540 MW).[7]

In Algeria, the forecast for electricity demand is established by operator system (OS) Sonelgaz Subsidiary, a state electricity and gas utility company. Based on the energy policy of the country, the OS matches supply to demand in two steps:

- Study electricity demand
- Define an equipment program to satisfy that demand at the lowest possible cost

Information on electricity generation in Algeria is shown in Figure 1.[8,11]

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



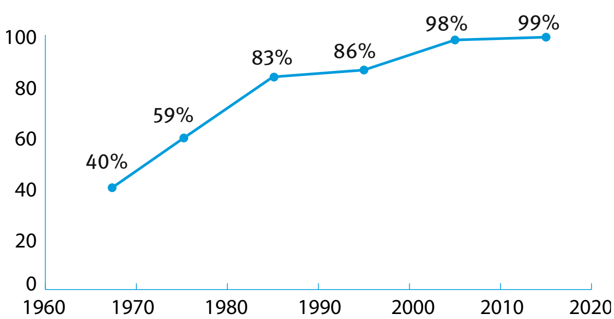
Source: CIA,[8] Sonelgaz[11]

Total installed power generation capacity amounts to 17.12 GW, approximately 50 per cent of which are open cycle gas turbines, 12 per cent combined cycle gas turbines, 35 per cent conventional steam turbines and 3 per cent hydropower. Over 98 per cent of the electricity production is based on natural gas, the balance originating from fuel oil/diesel and hydropower.

Algeria is one of the top 10 economies in Africa and plays a central role in the energy world, as it is a major producer and exporter of oil, natural gas (NG) and liquefied natural gas (LNG). Oil and gas export revenues account for more than 95 per cent of Algeria's total export revenues, around 70 per cent of total fiscal revenues, and 40 per cent of gross domestic product (GDP). Algeria exports NG through gas pipelines (to Italy via Tunisia and to Spain via Morocco and the Mediterranean Sea) and relies on it for domestic consumption. Algeria is the world's fourth-largest supplier of LNG, delivering 10 per cent of the gas consumed by Europe.

Electricity consumption in Algeria has been growing by almost 10 per cent each year since 2009, bringing it to 59,000 GWh in 2016. The total electrification rate is currently 99 per cent. The rate for urban areas rate is estimated to be 100 per cent and for rural areas 97 per cent (2016 est.).[11,12, 13]

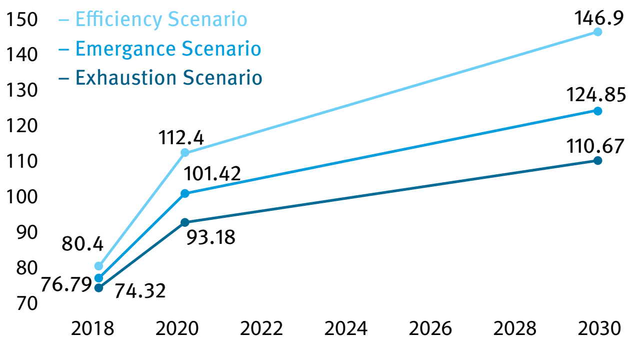
Figure 2.
Evolution of the rate of electrification over the period 1968 -2016 %



Source: Sonelgaz[11], Renewable Energy Portal[12] and World Bank[13]

Electricity prices are low in Algeria, especially for residential customers, mainly due to low internal prices for natural gas – approximately 0.06 US$/kWh for residential customers and a little over 0.03 US$/kWh for industrial users.[11] The growth in consumption at the various dates is summarized in Figure 3.

Figure 3.
Projected electricity demand (TWh)

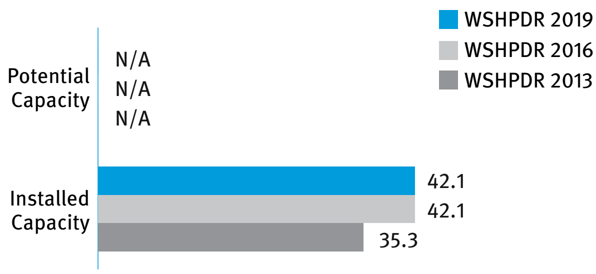


Source: Sonelgaz[14]

Small hydropower sector overview

The definition of small hydropower (SHP) in Algeria is defined as any plant with a capacity between 5 MW and 10 MW. Algeria also defines micro-hydropower as any plant with a capacity between 100 kW and 5 MW and pico-hydropower as any plant of less than 100 kW.[18] The installed capacity of SHP was 42.12 MW, while data on its potential capacity was not available.[19,27]

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



Source: *WSHPDR 2013*,[29] Ministry of Energy and Mines,[27] *WSHPDR 2016* [28]

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

The Ministry of Energy and Mining recorded that 103 reservoirs and more than 50 dams are in operation.[16] Algeria has approximately 269 MW of installed hydropower capacity (622 GWh/year), with plants of capacities between 1 MW and 100 MW. However, this energy source only plays a marginal role due to limited precipitation and high evaporation. Following the SHP definition of 10 MW for upper limit capacity, there are at least 42.12 MW of SHP installed (Table 1, 2015 est.).[19,27] SHP accounts for approximately 13 per cent of the total hydropower capacity. In the period between 1971 and 2010, the average contribution percentage of hydropower to the total electricity production was four per cent. The highest value was registered in 1973 (26.8 per cent) and the lowest value in 2002 (2 per cent).[20] Hydropower is expected to account for 1.2-1.3 per cent of electricity generation by 2025.[21]

Table 1.
Installed hydropower capacity in Algeria (MW)

Sites	*Installed capacity (MW)*
Mansouria	100.0
Darguina	71.5
Ighil Emda	24.0
Erraguene	16.0
Oued Fodda	15.6
Soukel Djemma	8.1
Ghrib	7.0
Gouriet	6.4
Bouhanifia	5.7
Tizi Meden	4.5
Tessala	4.2
Beni Behde	3.5
Ighzernchebel	2.7

Source: Ministry of Energy and Mining[20]

In 2014, the Government declared its intention to halt the operation of electricity production from hydroelectric dams and devote existing dam resources to irrigation and drinking water supply. The Ministry of Energy and Mining (MEM) stated that the needs of the population for water supply outweighed the importance of the electricity generated by the dams.[22] This sentiment was also echoed in the New National Programme for RE Development (2015-2030), which excludes hydropower from its roadmap for RE development.[23]

Renewable energy policy

The targets for the renewable energy technology are laid out in two phases, as outlined in Table 3.[15,16] By 2020, a target of 4.5 GW of RE should be installed. The planned geographical distribution of developments was justified as follows:

- Southern Region: hybridization of the existing power stations, supply to scattered sites
- High Plateau region: chosen for its solar and wind power potential
- Coastal Region: depending on the availability of land with roof and terrace exploitation

Competition from RE power generation is expected to diminish gas consumption as of 2020. One of the major objectives of the national RE programme is to save 300 billion m³ of natural gas, which is equivalent to eight times the national electricity consumption of 2014.[17] In its National Determined Contributions (NDC), the country announced its aim, through the RE programme, to reduce GHG emissions by 7 per cent by 2030.[9] The former Algerian Minister of Energy Noureddine Boutarfa has revealed that the reference price for the upcoming tender for 4 GW of solar capacity will not exceed 4 DZD/kWh (approximately 0.04 US$/kWh). The price is less than the average electricity price evaluated at 0.06 US$/kWh. Algeria has introduced a feed-in-tariff (FIT) scheme for photovoltaic installations. According to a new regulation published in the country's official journal (April 2014), ground-mounted solar parks of more than 1 MW of capacity will be eligible for the FIT. The FIT will be paid for a period of 20 years, albeit at different rates for the first five years and the following 15 years. A limit on the yearly number of hours for which the FIT will be paid has also been introduced.[24]

Table 2.
Renewable energy development programme 2015-2030 (MW)

Type	*2015-2020*	*2021-2030*
Photovoltaics	3,000	10,375
Wind	1,010	4,000
CSP		2,000
Cogeneration	150	250
Biomass	360	640
Geothermal	5	10
Total	**4,525**	**17,475**

Source: Stambouli,[15] Ministry of Energy [16]

The regulation does not define a cap for the amount of electricity that can benefit from FIT. The FIT for installations between 1 and 5 MW has been fixed at 15.94 DZD/kWh (0.2028 US$/kWh) for the first five years. For the following 15 years the FIT has been fixed at between 11.80 DZD/kWh (0.1502 US$/kWh) and 20.08 DZD/kWh (0.2555 US$/kWh), depending on the project. For solar parks with a power of more than 5 MW, the FIT has been fixed at 12.75 DZD/kWh (0.1622 US$/kWh) during the first five years, and between 9.44 DZD/kWh (0.1201 US$/kWh) and 16.06 DZD/kWh (0.2044 US$/kWh) for the following 15 years. The FIT will only be paid for a limited number of hours per year, above those hours the electricity can be sold at conventional prices.[24]

The renewable electricity goals of Algeria are set out as percentage values of overall power generation. Algeria has one of the highest solar economic potentials in the world, estimated at 13.9 TWh/year for photovoltaics and 168,972 TWh/year for thermal. The wind potential in the country is 35 TWh/year. Algeria has a nationwide environment strategy, a national plan for environmental action and sustainable development.

The National Plan for Environmental Action and Sustainable Development adopted in 2002 focuses on reducing pollution and noise, preserving biodiversity and natural spaces, and raising public awareness of and providing training about environmental issues.[25] To address territorial disparities in

Algeria and create conditions for sustainable and harmonious growth throughout the country, a national development plan (Schéma national d'aménagement du territoire, SNAT) adopted in May 2010, sets out the country's long-term vision until 2025, aiming to gradually reduce regional inequalities and enhance the attractiveness of areas lagging in development.[26]

The integration of RE into the national energy mix, preservation of fossil resources and diversification of electricity production poses a major challenge to Algeria, yet will make a vital contribution to the country's sustainable development. The National Programme for the Development of RE 2011-2030 (Programme national de développement des énergies renouvelables) was adopted by the government in February 2011. The programme saw a first phase focused on pilot and test projects of the different available technologies. During this phase, up-to-date technological developments were made available in the energy arena, and subsequently a review of the programme was conducted.

The renewable energy programme aims expand the use of solar power and photovoltaic systems and, to a lesser extent, wind power. It plans to install 22 GW between 2011 and 2030 (12,000 MW for the domestic consumption and 10,000 MW for export), which represents 40 per cent of total energy consumption from the renewable sources by 2030.[16] The programme contributes to the large-scale development of photovoltaic and wind fields, the introduction of biomass field (waste valuation) and geothermal generation. The development of the solar thermal programme (CSP) has been postponed until 2021. More than 4,500 MW of additional capacity will be installed before 2020.[27] Should the programme be successfully implemented, 27 per cent of national electricity production will be from renewables by 2030.[27]

Barriers to small hydropower development

All forms of hydropower in the region face potentially stagnating rates of expansion due to geographical and climatic limitations. In Algeria, these include:

- The aridity of the southern region of the country, where rainfall is scarce
- Limitations to the locations in which hydropower projects can be implemented
- The perception by the Government of Algeria and private investors of the hydropower sector as unattractive
- High evaporation levels and the frequent occurrence of droughts[28]

Moreover, the Government has stopped the production of electricity from dams, and has decided to close the country's hydroelectric power plants. The dams previously producing electricity are now used for irrigation and to provide the population with drinking water.

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1.3.2

Egypt

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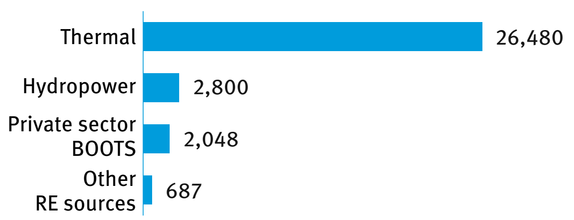
Key facts

Population	88,487,396[1]
Area	1,001,450 km[2]
Climate	Throughout Egypt, days are typically warm or hot, and nights are cool. Egypt has only two seasons: a mild winter from November to April, and a hot summer from May to October. Variations in daytime temperatures and changes in prevailing winds are the major differences between the seasons. Mean daily temperatures are 27.6 °C in July and 13.6 °C in January.[2]
Topography	A vast desert plateau is dissected by the Nile Valley and Delta. The Sinai Peninsula in the east connects Africa to the Asian continent. The Nile Delta is a broad, alluvial land, sloping down to the sea for 160 km. South along the Nile River, most of the country (known as Upper Egypt) is a tableland rising to approximately 460 metres. Altitude ranges from 133 metres below sea level in the Libyan Desert to 2,629 metres above in the Sinai Peninsula.[3]
Rain pattern	Egypt receives less than 80 mm of precipitation annually in most areas, although in coastal areas precipitation levels reach 200 mm.[3]
Hydrology	The country's main river is the Nile, widely regarded as the longest river in the world at 6,853 km. The Nile enters Egypt at the Sudanese border in the south and has no non-seasonal tributaries for the entire length of the country. Before flowing into the Mediterranean, the river splits off into a number of distributaries in the Nile Delta. Other important water systems include the Suez Canal, the Alexandria-Cairo Waterway and Lake Nasser.[3]

Electricity sector overview

In 2015, Egypt had a total installed capacity of 32,015 MW. Thermal power accounted for most of this – almost 83 per cent. Hydropower accounted for approximately 9 per cent; privately owned build, own, operate, transfer (BOOT) plants for 6 per cent and other renewable sources for 2 per cent (see Figure 1).[4]

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

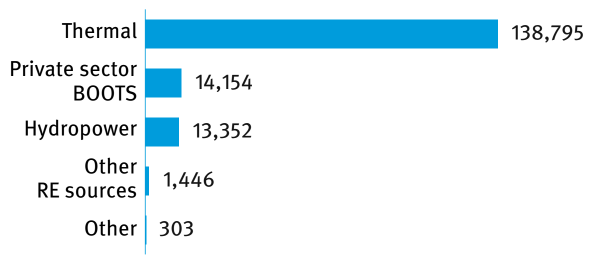


Source: EEHC[2]

In 2013/14 total generation was 168,050 GWh, with thermal power plants contributing approximately 83 per cent, private sector BOOTs 8 per cent, hydropower 8 per cent, and other renewable sources less than 1 per cent. Other sources, including isolated plants and energy purchased from independent power producers (IPPs), provided a negligible amount (see Figure 2). The peak load in the same year was 26,140 MW, down 3.2 per cent from the previous year.

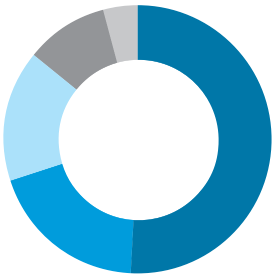
In 2013, 120,826 GWh were sold through distribution companies to low and medium voltage end users, more than half of whom were residential consumers. Meanwhile 21 percent and 16 per cent were sold to industrial consumers and the government and public utilities sector respectively. The commercial sector accounted for only 3 per cent of sales (see Figure 3).[2]

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



Source: EEHC[2]

Figure 3.
Energy sold by sector in Egypt (medium and low voltage) (%)



Source: EEHC[2]

The Egyptian energy sector is a mixture of both state-owned and private companies in the form of Independent Power Producers (IPPs) and BOOTs. The state-owned and operated Egyptian Electricity Holding Company (EEHC) coordinates, supervises and monitors the activities of its subsidiary companies which are responsible for generation, transmission and distribution. In terms of generation, subsidiaries are divided by regions of responsibility with the addition of the Hydro Plants Generation Company. The Egyptian Electricity Transmission Company (EETC) is responsible for the countrywide transmission of electricity to regional and local distributors with distribution companies based upon region.[5] The Ministry of Electricity and Energy (MEE) is the principle policy maker and supervises all activities related to energy projects, as well as suggesting electricity prices and publishing data and statistics relating to electricity production. The New and Renewable Energy Authority (NREA) was established in 1986 to promote both renewable sources of energy and energy efficiency, and efforts to develop and introduce renewable energy technologies on a commercial scale. The Egyptian Electric Utility and Consumer Protection Regulatory Agency (EgyptERA) was established in 1997 to balance the interests of electricity producers, electricity providers and end users. It is considered the industry watchdog responsible for licensing the construction and operation of electricity generation, transmission and distribution facilities, as well as for electricity trading. In 2012/13, the EEHC accounted for more than 90 per cent of total electricity generation in the country, with BOOTs providing 8.66 per cent and IPPs 0.02 per cent.[3]

In 2013/14, the grid consisted of 44,220 km of transmission lines and cables ranging from 33 kV to 500 kV. The grid is subdivided into six geographical zones, namely Cairo, Canal, Delta, Alexandria and West Delta, Middle Egypt and Upper Egypt. The country's entire territory is covered, but there are 30 power plants, mainly gas and diesel, as well as one 5 MW wind farm, that are not connected to the grid and are installed in remote areas to provide electricity to tourist sites. The Egyptian network is interconnected with Libya, Jordan, Syria and Lebanon, with ongoing studies investigating the possibilities for interconnections with Saudi Arabia, Sudan, the Democratic Republic of the Congo, the Eastern Nile Basin (Sudan and Ethiopia) and Greece.[2]

A combination of increasing demand, decreasing production and high subsidies for fuel have put a strain on the Egyptian energy sector and led to an enormous public deficit. As of June 2014, Egypt owed US$ 7.5 billion to foreign oil and gas companies.[7] In order to cover growing demand, the five-year plan for 2012-2017 expects to invest approximately 103 billion Egyptian pounds (US$ 16 billion) in the construction of new power stations, substations, transmission and distribution networks, and the renovation of existing networks.

Table 1.
Tariff structures in Egypt

Sector type	*Energy price (EGP/kWh ((US$/kWh))**
Power service on extra high voltage (Pt/KWh)	
Kima	0.047 (0.007)
Metro- Ramsis	0.079 (0.013)
Sumed (Arab Petroleum Pipelines Company)	0.316 (0.050)
Other consumers	0.150 (0.024)
Power service on high voltage (Pt/KWh)	
Metro - Toura	0.131 (0.021)
Other consumers	0.182 (0.029)
Power service on medium & low voltage	
More than 500 KW	
Demand charge (LE/kW-month)	0.100 (0.016)
Energy Rates (Pt/kWh)	0.250 (0.04)
Up to 500 KW	
a-Agriculture (Pt/KWh)	0.112 (0.018)
Annual charge per fedan for Irrigation by groups (LE/Fedan)	1.352 (0.214)
b-Other purposes (Pt/KWh)	0.290 (0.046)
4- Residential	
First 50 KWh monthly	0.050 (0.008)
51 - 200 KWh monthly	0.120 (0.019)
201 - 350 KWh monthly	0.190 (0.03)
351 - 650 KWh monthly	0.290 (0.046)
651 - 1000 KWh monthly	0.530 (0.084)
More than 1000 KWh monthly	0.670 (0.106)
Commercial	
Description Price (Pt/KWh)	
First 100 kWh monthly	0.270 (0.043)
101 - 250 kWh monthly	0.410 (0.065)
251 - 600 kWh monthly	0.530 (0.084)
601 - 1000 kWh monthly	0.670 (0.106)
More than 1000 kWh monthly	0.720 (0.114)
Public lighting	0.475 (0.075)

Source: EgyptERA[6]

Note: * Prices are based on a power factor of 0.9

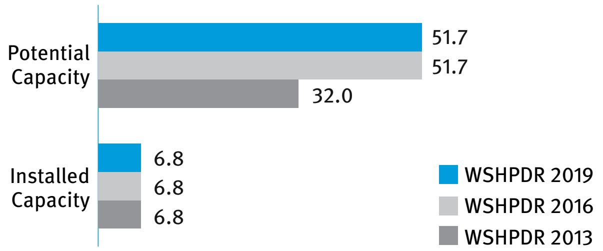
Alongside the NREA, the EEHC hopes to add 2,980 MW of capacity from renewable sources as part of the five-year plan for 2012-2017 and to encourage the private sector to share in the implementation of these projects. In addition, the National Energy Efficiency Action Plan has been implemented. This aims to increase efficiency across a range of sectors, and will also launch a media awareness campaign.[2]

Tariffs in Egypt are some of the lowest in the world with government subsidies for the residential sector totalling 13.2 billion Egyptian pounds (US$ 2 billion) in 2012/13. In 2013/14 total energy subsidies across all sectors reached 144 billion Egyptian pounds (US$ 23 billion) and, as of July 2014, the Government sold electricity for less than half its production cost. Since 2012, the subsidies have been slowly reduced as part of a five-year plan that will see energy prices double by 2017.[8] Table 1 provides tariffs by sector.[7]

Small hydropower sector overview

There is no official definition of small hydropower in Egypt, so this report assumes a definition of 10 MW or less. There is an estimated installed small hydropower capacity of approximately 6.8 MW with an estimated total potential capacity of almost 52 MW, indicating that 13.2 per cent has been developed.[9,10,11,12] Compared to the *2013 World Small Hydropower Development Report* installed capacity has remained unchanged (see Figure 4).[13]

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



Source: Various[6,7,9,10,13,16]

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

The country's Hydro Power Plants Executive Authority (HPPEA) is responsible for the study, execution and development of hydropower projects. Current installed capacity comes from four operational plants, Small Naga Hamadi, El Lahun, El Faiyum and El Azabthree. Three plants with a total capacity of 6.6 MW have been planned, while feasibility studies estimate a potential additional capacity of approximately 45 MW (see Table 2).

There are currently five large hydropower plants in operation, all located on the River Nile. Total installed capacity is approximately 2,800 MW, the majority of which, 2,100 MW, is found in the Aswan High Dam. Small hydropower plants contribute less than 2 per cent of the total capacity. There is a general consensus that at least 85 per cent of the country's potential hydropower has already been developed. Hydropower therefore does not feature prominently in the Government's plans for the renewable energy development.[14]

A feed-in-tariff scheme introduced in 2014 for renewable energy sources does not include hydropower (see below).

Renewable energy policy

In February 2008, the Government adopted the New National Renewable Energy Strategy, which has the target of having 20 per cent of the country's total annual electricity generation coming from renewable resources by 2020. Wind energy is seen as key to achieving this, with 12 per cent of total capacity (7,200 MW) expected to come from wind farms alone.[15] Six per cent is expected to be achieved from existing hydropower structures and two per cent from other renewable sources, especially through the development of solar resources.[2]

Table 2.
Installed and potential small hydropower capacities

Plant name	*Capacity (MW)*
Operational	
Small Naga Hamadi	4.5
El Lahun	0.8
El Faiyum	0.8
El Azab	0.7
Planned	
Zefta	5.5
El Sekka/El Hadeed	0.55
Wadi El Rayan	0.55
Potential small hydropower sites	
Damitta Spans	6.5
Rashed Spans	4.6
Assiut Regulator	3
Tawfiki Rayah	2.45
Beheri Rayah	2.2
Abbasi Rayah	1.85
Edfina Barrage	1.85
Sharkawia Canal	1.85
Menoufi Rayah	1.8
Ibrahimia Canal Intake	1.55
Tawflky Intake	1.2
Yosfly Sea Intake	1.2
Adfena Canal	1
Apassy Intake	1
Bahr Yousef Canal	1
El Mokhtalat	1
Elkarneen Intake	0.75
Gamagra Spans	0.75
Lahawan Spans	0.6
Mansoma Intake	0.5
Bagoria Intake	0.4
Elkalabla Canal	0.38
Elnasary Intake	0.38
Habab Weir	0.18

Plant name	*Capacity (MW)*
Asfon Canal	0.15
Elseka Elhadid Spans	0.15
Total	**51.69**

Source: Various[6,7,9,10]

One third of the planned capacity will be state-owned projects, financed through the public investments by the NREA in cooperation with international financing institutions. Two thirds are intended to be private sector projects, supported by policies structured in two phases:

- Phase 1 will adopt competitive bids through issuing tenders requesting the private sector to supply electricity from renewable energy sources.
- In Phase 2, a feed-in-tariff will be implemented, in particular for medium and small size projects.[12]

Incentives for investors include:

- Approving private sector participation through competitive tender and bilateral agreements
- Reducing project risks through signing long term, Government-guaranteed, Power Purchase Agreement (PPA) for 20-25 years
- The selling price for the energy generated from renewable energy projects will be in foreign currency in addition to a portion, covers operation and maintenance costs, in local currency.
- Investors will be issued and can sell certificates of emission reduction.
- Evaluation criteria for tenders of the renewable energy projects will give privilege for local component.
- All renewable energy equipment and spare parts are exempt from customs duties & sales taxes.

In September 2014, the Government approved the issuance of feed-in-tariffs for solar PV and wind projects, with fixed feed-in-tariffs over 25 years for PV and over 20 years for wind. These range from US$ 0.046 for wind farms in the highest operating hours category to US$ 0.143 for solar PV plants between 20 MW and 50 MW installed capacity. These tariffs will be adjusted as soon as the following ceilings are reached: 300 MWh of small PV (< 500 kW), 2,000 MWh of medium PV (500 kW – 50 MW), and 2,000 MWh of wind. Installations from 500 kW and above, including both the medium and high voltage connected installations, are defined in United States dollars. Although payment will be offered in Egyptian pounds, the Government of Egypt bears the exchange rate risk. The FIT scheme is complemented by Law 203/2014 of 22 December 2014, whereby the EETC and local distribution companies are obliged to connect a renewable energy project to the grid. While the costs of connections are borne by the producer, the Government funds any extension of the grid. They are also obliged to purchase the electricity generated by qualifying projects and, if this is not feasible, compensate the producer.

Barriers to small hydropower development

The key barriers to small hydropower development are:

- The lack of government interest, and the favouring of a renewable energy policy based largely on wind and solar energy
- Without any financial incentives being given to small hydropower, it will be difficult to attract investment over other more favourable RE options.
- Better studies of SHP potential should be carried out. The lack of interest in SHP stems from a general consensus that some 85 per cent of the Nile River has already been developed for hydropower, meaning that the NREA stands to make better marginal gains and garner better financial support by looking into other untapped non-hydro resources. Nonetheless, this assessment is largely based on a perspective from large hydropower projects. More accurate studies on small hydropower may reveal the existence of significant undeveloped potential.

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1.3.3 Morocco

International Center on Small Hydro Power (ICSHP)

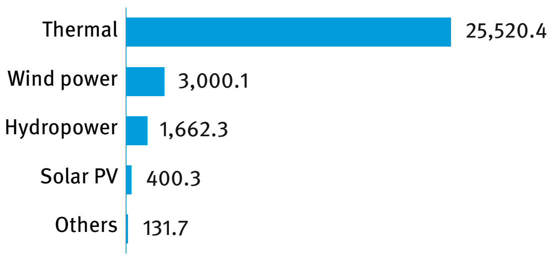
Key facts

Population	35,095,498[1]
Area	446,550 km[2]
Climate	Morocco is characterized by a diverse climate. In the northern coastal regions, temperatures are generally mild, reaching an average of 14 °C. In highlands and mountains, usually below 0 °C, temperatures can reach -20 °C, causing frost on the plateaus and significant snowfall in the mountains. Summers are hot and dry with mean temperatures of 24 °C on the coast and above 35 °C, sometimes exceeding 40 °C, in the country's interior.[2]
Topography	Morocco has four mountain ranges. The Rif chain extends in an arc parallel to the Atlantic Ocean in the West. The High Atlas, about 80 km in breadth, extends eastward for 700 km. Mountain Toubkal is the highest point of the massif (4,165 metres). The Middle Atlas and Anti Atlas are the other two massifs. Beyond the chains of the Atlas, one finds Pre-Saharan and Saharan Morocco, where the large Hamadas form rugged desert plateaus, plateaus covered with pebbles *(reg)* or dunes *(erg)*.[2]
Rain pattern	In the north, winters are generally wet and mild with decreasing cumulative annual rainfall from north to south, (1,000 to 200 mm/year) with peaks in the mountainous regions (2,000 mm/year in the Rif and 1,800 mm/year in the Middle Atlas). In southern regions, rainfall is very rare and irregular. Most regions have on average less than 130 mm of rain per year, with the exception of rare humid, tropical air surges, which give rise to rainfall in the form of showers.[2]
Hydrology	The most important and permanent rivers of North Africa are in Morocco: Loukos (100 km), Sebou (500 km), Bouregreg (250 km), Moulouya (450 km), Daraa (1,200 km), Oum Rbia (600 km), Tensift (270 km), and Ziz (270 km).[2]

Electricity sector overview

Compared with other countries in the Middle East and Northern Africa (MENA), Morocco is characterized by a lack of conventional hydrocarbon resources and high energy import.[3] At the end of 2016, electricity generation was 30,714.9 GWh. Approximately 55 per cent of the electricity generated was from coal (16,861.7 GWh), almost 19 per cent from natural gas (5,908.7), 9 per cent from fuel (2,750.2 GWh), 10 per cent from wind power plants (3,000.1 GWh), 5 per cent from hydropower (1,662.2 GWh), 1.5 per cent from concentrating solar power plants (400.3 GWh) and roughly 0.5 per cent from others (131.7 GWh) [22]

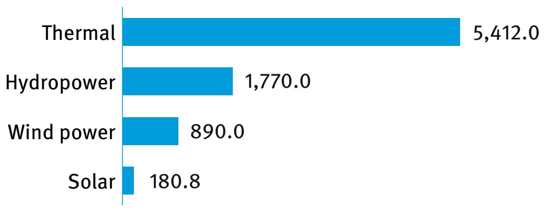
Figure 1.
Annual electricity generation by source in Morocco (GWh)



Source: ONEE[22]

In 2016, the installed electricity capacity of Morocco was 8,252.8 MW, as shown in Figure 2.[10] Hydropower plants account for 1,770 MW, while 5,412 MW comes from steam power plants, gas turbines and diesel generators, 890 MW from wind farms and 180.8 MW from solar power.

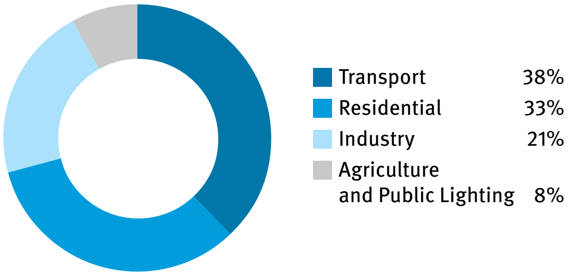
Figure 2.
Installed electricity capacity by source in Morocco (MW)



Source: Brahim[10]

National primary energy demand, whose distribution by customer class is presented in Figure 3, grew on average by nearly 5 per cent annually in recent years, driven by growth in electricity consumption, which has increased on average by 6.5 per cent per year due to progress achieved in rural electrification and the dynamism of the economy.[4] The primary energy consumption of Morocco is projected to double between 2015 and 2030, and its electricity demand is expected to increase 2.5 times.[3]

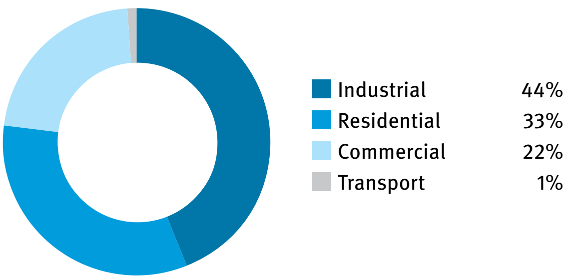
Figure 3.
Primary energy consumption by customer type (%)



Source: Driss et al.[6]

The electricity sector of Morocco has developed impressively since 1990, by diversifying generation, improving security of supply, and reaching almost universal access to electricity.[6] Its distribution by customer type is presented in Figure 4. The electricity sector in Morocco is dominated by the state-owned operator, Office National de l'Electricité et de l'Eau Potable (ONEE). This operator has the status of single buyer of power produced, except for renewables generation, where a specific law allows private to private power transactions.[7] ONEE owns the total transmission network and much of the distribution network. It can give concessions to private operators through purchase guarantees.[8]

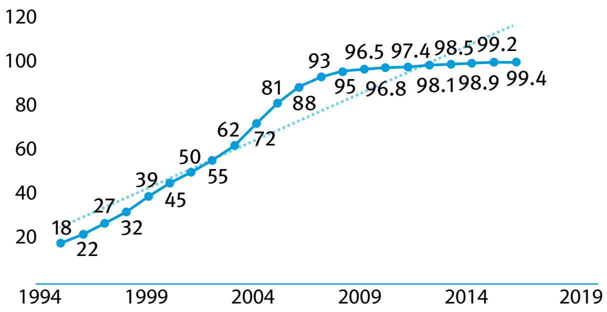
Figure 4.
Electricity consumption by customer type (%)



Source: IEA[9]

Until 1995, only 18 per cent of the Moroccan population had access to electricity. Around 12 million citizens had access to electricity over the last 20 years through the Program of Rural Electrification (PERG). The Morocco's electrification rate today is close to 100 per cent, meaning it sets an example for the whole region of Northern African.[7, 11] The graph below shows the evolution in electrification rate between 1994 and 2018.

Figure 5.
Evolution of electrification rate between 1994 and 2018 (%)



Source: Brahim[10]

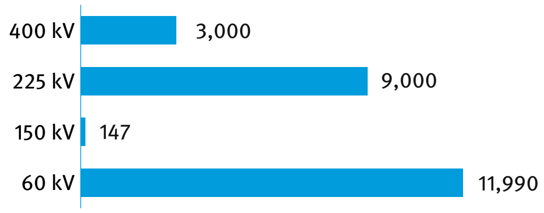
Note: The dotted line represents the trend of increasing access to electricity in Morocco.

At the COP 21 summit held in Paris, the second Moroccan target of the renewable energy policy was announced. It was estimated that by 2030, renewable energy generation will account for 52 per cent of total installed electricity generation capacity.[11] Following the introduction of Law 13-09 in 2010, Morocco adopted a new regulatory framework for the electricity sector in 2012, allowing the exchange of electricity from renewable sources between producers and customers connected to the very high-voltage and high-voltage (VHV/HV) Moroccan electricity grid.[11]

As the sole buyer, ONEE supplies the national market through its own plants, those of independent power producers (IPPs), and through a number of private industrial producers. IPPs comprise three plants, two of which are the largest in the country: the Jorf Lasfar Energy Company (JLEC) (coal), the Electrical Energy Company of Tahaddart (gas, combined cycle) and the Compagnie Éolienne du Détroit (CED).[11]

Domestic production only covered 85 per cent of Moroccan consumption in 2016. Morocco is a net importer of electricity. Almost all the electricity is imported from Spain, which is connected synchronously by a 400 kilovolts (kV) interconnection with a 1.4 GW capacity. This double underwater alternating current line connects the Moroccan grid to the Spanish grid under the Strait of Gibraltar. The synchronous interconnection with the Algerian grid has a 1.2 GW capacity.[11] Since 1988, a 400-kV transmission line has linked Morocco to Algeria. The transmission capacity has been increased to 1.7 GW with the installation of a second line and then a third, commissioned in 2009. A feasibility study is currently being carried out for an interconnection with Mauritania and other countries in West Africa.[11]

Figure 6.
National electricity transmission network (km)



Source: PAREMA[11]

Electricity tariffs are not uniform in Morocco. The customers connected to the ONEE distribution grid are subject to tariffs that are set and reviewed by Order of the Minister Delegate to the Head of Government in charge of General Affairs and Governance, on the advice of an Inter-Ministerial Pricing Committee. The tariffs applied by private delegated management authorities to their customers are set and reviewed in keeping with the delegated management contracts, but remain similar to ONEE rates.[11] There are different tariffs, depending on the consumer categories. Tariffs applied to households are incremental based on monthly consumption, but do not take into account the household's socio-economic situation. Table 1 details the change in tariffs, according to monthly consumption.

Table 1.
Variation of electricity tariffs according to monthly consumption

Monthly consumption	*Tariffs*
0 kWh - 100 kWh	0.098 US$/kWh
101 kWh - 200 kWh	0.11 US$/kWh
201 kWh - 500 kWh	0.12 US$/kWh
> 500 kWh	0.16 US$/kWh

Source: ONEE[11]

Rural populations are subject by ONEE to pricing based on a prepaid meter. These rates, depending on the type of use and consumption bracket, fluctuate between 0.12 US$/kWh and 0.15 US$/kWh.[11] Table 2 below shows the hourly variations of electricity prices.

Table 2.
Hourly variations of electricity prices (industrial sales)

	Winter (October – March)	*Summer (April – September)*
Super-peak hours	18:00 to 20:00	19:00 to 21:00
Peak hours	17:00 to 18:00 and 20:00 to 22:00	18:00 to 19:00 and 21:00 to 23:00
Regular hours	07:00 to 17:00	07:00 to 18:00
Off-peak hours	22:00 to 07:00	23:00 to 07:00

Source: ONEE[13]

Multiple changes were experienced in the electricity sector due to the competitive production and commercialization of electrical energy from renewable energy sources, for customers connected to Very High Voltage (VHV) / High Voltage (HV) / Medium Voltage (MV), in accordance with Law 13-09 on renewable energy. The creation of a regulatory agency has been announced by the new Law 48-15.[14] The mission of the new agency will also focus on the natural gas sector, assessing the increasing share of natural gas in the Moroccan energy mix to secure the energy supply of the country at the lowest cost.[15]

Small hydropower sector overview

In accordance with the classification established by the International Union of Electric Power Distributors, four categories are distinguished in Morocco: the pico-power plant (less than 20 kW), the micro-power station (from 20 kW to 500 kW), the mini-power station (from 500 kW to 2 MW), and the small power station (from 2 to 10 MW).[16] The available statistics relate exclusively to the small hydropower plants (Table 3). The installed capacities of the Imfaout, Teza and Sefrou plants are unknown. The present report estimates the total installed capacity at 38.4 MW. Compared to the *World Small Hydropower Development Report 2016*, the installed capacity has remained the same (Figure 7), due to limited data on the Imfaout, Taza and Sefrou power plants, and the current lack of information on modernization plans in the region. Estimated potential capacity has increased significantly, due to the 125 new-sites recently identified by ONEE.[13]

Figure 7.
Small hydropower capacities 2013/2016/2019 in Morocco (MW)

Source: PAREMA,[11] ONEE,[13] *WSHPDR 2013*,[21] *WSHPDR 2016* [20]

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

Table 3.
Installed small hydropower plants up to 10 MW in Morocco

Plant name	*Installed capacity (MW)*	*Generation in 2014 (MWh)*
Alkanser	8.3	19
Bouareg	2.3	3
Mansour Eddahbi	10	15.2
Daourat	8.5	1.1
Takerkoust	4.4	6.1
Imfaout	N/A	22
Taza	N/A	2.4
Sefrou	N/A	1.3

Source: ONEE[17]

In addition to some potential sites identified by the Development Centre of Renewable Energies in the 1990s (Table 4), the ONEE has recently identified 125 new sites suitable for locating small (2 MW – 10 MW) or micro hydropower plants (100 kW to 2 MW), with a total potential capacity estimated at 306.6 MW.[11]

Table 4.
Identified potential of small hydropower plants in some regions of Morocco

Regions	*Number of sites*	*Identified potential (kW)*
Haouz	86	2,069.8
Khenifra	62	4,500.5
Chefchaouer	5	86.0
Total	**153**	**6,656.3**

Source: Dahbani[18]

More than 100 MW of small hydropower plants will be developed by the private sector in the framework of Law 13-09 relating to renewable energy.[13] One of the few operators on the MCH market, Platinum Power, has a portfolio of seven MCH projects, five of which are upstream of the Bin El Ouidane dam, on the Ahansal river.[19]

Renewable energy policy

In 2009, Morocco adopted its National Energy Strategy (NES), which contained targets for 2020, renewing it again prior to the climate negotiations during COP 21 in Paris.[6] The country intends to raise the share of renewables in its total installed capacity from 42 per cent in 2020 to 52 per cent in 2030. The 2016-2030 period will therefore see the development of 10,100 MW of renewable energy (RE) (20 per cent solar, 20 per cent wind and 12 per cent hydropower), which corresponds to 52 per cent of a total installed capacity of 24,800 MW in 2030. Through these programmes, Morocco aims to ensure its energy independence, reduce its greenhouse gas emissions and diversify its energy mix. While no significant developments have taken place as of yet, aligning existent sectoral policies to renewables policy framework will represent greater leaps towards an integrated Low-Carbon Development strategy, based on high shares of RE.[6]

In 2008, Law 16-08 increased the threshold for renewable energy domestic production from 10 MW to 50 MW. It also granted access to the transmission network to facilitate generating power from renewable sources and allowed the signing of private concession agreements for electricity generation from domestic energy resources. Law 16-08 also allows operators to sell ONEE their occasional surpluses of electric power generated from domestic energy resources.[12]

Aside from the law on self-generation, Law 13-09 was implemented in 2010. It sets out the legislative framework for the promotion of renewable energy sources. The law removed the power limitations for certain types of energy and further liberalized the renewable energy sector.[6] This law has also recently been amended (Law 58-15) to open up the low-voltage network to private producers and increase the capacity ceiling of small hydropower projects from 12 to 30 MW. These measures will enable clients from the tertiary and residential sectors to develop renewable energy capacities and feed any excess production into the low-voltage network.[3]

Since 2008, Morocco has experienced a period of rapid change in its power sector, and especially in its energy transition policy, by focusing on harnessing its huge renewable energy potential with a focus on solar and wind energies.

Barriers to small hydropower development

There are multiple barriers to small hydropower development in Morocco. Some of the most important ones are the following:

- Small hydropower projects are less attractive in comparison to other renewable energy sources such as solar and wind power, where the investment returns are higher
- Lack of awareness of the population with regards to SHP development benefits
- Low commitment from the policies and from the civil society to SHP
- Low level of interest in the research and development (R&D) projects in the university on SHP.[6,20]

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Sudan

1.3.4

Abdeen Mustafa Omer, Energy Research Institute

Key facts

Population	39,578,828[1]
Area	1,861,484 km[2]
Climate	The climate is tropical sub-continental, with a wide range of variations, from a desert climate in the north to an equatorial climate in the south. The mean temperature ranges between 30 °C and 40 °C in summer and between 10 °C and 25 °C in winter.[2]
Topography	Sudan is a landlocked country consisting of a gently sloping plain, with the exception of Jebel Marra, the Red Sea Hills, Nubba Mountains and Imatong Hills. Its main features are alluvial clay deposits in the central and eastern regions, stabilised sand dunes in the western and northern regions and red ironstone soils in the south. The highest point is Kirson Tonga in the south of the country reaching 2,799 metres.[2]
Rain pattern	The average annual rainfall is 416 mm but ranges between 25 mm in the north and over 1,600 mm in the south. The rainy season lasts from July to October, but is shorter in the north.[2]
Hydrology	Sudan is rich in water resources from the Nile system. Surface water resources are estimated at 84 billion m^3, while the total quantity of groundwater is estimated to be 260 billion m^3.[2]

Electricity sector overview

Total installed capacity in 2017 was 3,400 MW, with hydropower generation capacity (small and large) at 1,593 MW and remaining capacity coming from thermal power plants including diesel, gas, steam and combined power (Figure 1).[4] Total electricity generation in 2016 was 14,871 GWh, while consumption stood at 11.795 GWh.[5,6] The national electrification rate in 2016 was 38.5 per cent, with 70 per cent in urban areas and 22 per cent in rural areas.[1]

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

Source: Omer[4]

The Ministry of Energy and Mining (MEM) is in charge of the energy sector in general, while the Ministry of Water Resources and Electricity is responsible for electricity generation. The National Electricity Corporation, which operates under the MEM, owns and operates hydropower plants, isolated diesel systems, thermal and steam plants. The state-owned Sudanese Electricity Transmission Company Ltd and the Sudanese Electricity Distribution Company manage transmission and distribution respectively. The Electricity Regulatory Authority is the sector regulator.[7]

The power sector of Sudan has been characterized by a significant deterioration of generation and network equipment, the dominant position of oil generation and an absence of necessary reserves to cover peak demand. The imperfection of both tariff and pricing policies for energy systems further complicates the situation. However, recent changes in legislation aim to promote new projects, modernize the country's power sector and enable a greener energy future.[8] In 2015, the Sudanese Parliament passed the National Electricity Bill to provide the establishment of a regulatory framework to govern the generation, transmission, supply, distribution, export and import of electricity and system operation. The Government has implemented measures to separate power generation, transmission and distribution as well as made the first steps towards the privatization of the energy sector.[9] The country has a generation and transmission programme aiming to increase total capacity to 9,156 MW, including 1,573 MW from renewable energy sources (excluding large hydropower), by 2031.[10]

The major hydropower plant in Sudan is the 1,250 MW Merowe plant on the River Nile, approximately 350 km north of Khartoum, which was completed in 2009. It has ten 125 MW units and thus a total capacity of 1,250 MW. The Kajbar Dam, with a generation capacity of 360 MW, is another large hydropower plant on the River Nile that has been proposed by the Government. The Chinese Sino Hydro has stated that it would finance 75 per cent of the US$ 200 million project, with the Sudanese Government providing the remaining 25 per cent. Environmental groups have expressed concern about the Kajbar project, citing potential damage to the Nile ecosystem and the displacement of Nubian residents from the area.[11] The project has not yet been completed. End consumer electricity tariffs range from SDP 0.16 (US$

0.042) per kWh for industrial consumers, to SDP 0.34 (US$ 0.029) per kWh for commercial consumers (Table 1).[12]

Table 1.
Consumer electricity tariffs by consumer type in Sudan

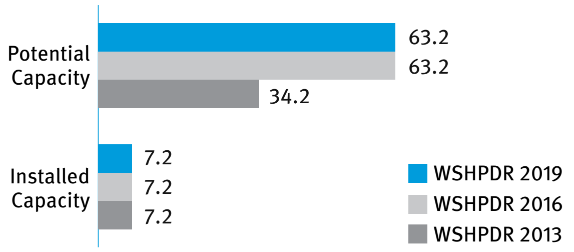
Consumer category	*Tariff (SDP (US$) per kWh)*
Industrial	0.16-0.18 (0.042-0.047)
Commercial	0.34 (0.089)
Governmental	0.70 (0.183)
Agricultural	0.16 (0.042)
Residential (> 200 kWh per month)	0.26 (0.068)
Residential (1-200 kWh per month)	0.15 (0.039)

Source: RCREEE[12]

Small hydropower sector overview

The Government of Sudan defines small hydropower (SHP) as any hydropower plant with a capacity between 500 kW and 5 MW. The Government also defines mini-hydropower as any plant with a capacity of 50 kW to 500 kW, and micro-hydropower as any plant of less than 50 kW.[23] As of 2017, the total potential capacity of SHP was estimated at 63.2 MW, while the installed capacity (for SHP up to 10 MW) was 7.2 MW from a sole SHP plant El Girba 2, with three 2.4 MW units.[5] Compared to the results of the *World Small Hydropower Development Report (WSHPDR) 2016*, both installed and potential capacities of SHP in Sudan have remained unchanged, as no new plants have been commissioned and no new studies have been carried out (Figure 2).

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



Source: *WSHPDR 2016*,[7] Abuaglla,[11] Omer,[19] *WSHPDR 2013* [21]

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

There have been no countrywide studies estimating the potential of SHP in Sudan. However, the Government has established a renewable energy target which aims to install 56 MW of additional SHP plants by 2031.[10] Therefore this report assumes that the potential is at least 63.2 MW. Although there have been no countrywide studies, a number of prospective sites have been identified for SHP development, using waterfalls with heads ranging from 1 to 100 metres.

Table 2.
Operating hydropower plants in Sudan (MW)

Name	*Year*	*Installed capacity*
Sennar	1962	15.0
Roseires	1972	280.0
Girba 1	1964	10.6
Girba 2	1964	7.2
Jabal Aulia	2003	30.4
Merowe	2009	1,250.0

Source: Abuaglla [11]

In addition, water from the River Nile could be used to run in-stream turbines, with water then being pumped to riverside farms. There are more than 200 suitable sites for the use of in-stream turbines along the Blue Nile and the main River Nile. The total potential of mini-hydropower plants is estimated at 67 GWh for the Southern Region, 3,785 MWh in the Jebel Marra and 4,895 MWh in the El Gezira and El Managil canals.[13]

Renewable energy policy

Although Sudan possesses substantial potential renewable energy resources, only a fraction of these have been developed so far. There is no regulatory or legal framework targeting renewable energy specifically. There is no obligation to conclude long-term power purchase agreements with renewable energy producers, no feed-in tariffs, no net-metering policy for small-scale projects and no priority access for renewable energy granted by law. However, the country's Electric Regulatory Authority has already undertaken a study on the cost of electricity and the tariff structure, including the feed-in tariffs (FIT). Currently the Government is developing a FIT programme to encourage both grid-connected and off-grid renewable energy projects, with the support of the United Nations Development Programme.[9]

Barriers to small hydropower development

Key barriers to the development of SHP in Sudan include:

- Low level of public awareness of the economic and environmental benefits of SHP
- Generally low levels of individual income
- Poor pricing of hydropower plants, especially in the local market
- Weak institutional capabilities of the various energy research institutes
- Problems with data collection, which hinders the development of energy policies and the design of a sustainable strategy with various energy mix options
- Absence of an effective project plan and delivery, as well as a lack of experts in the renewable energy sector

- Projects tend to end up being much more expensive than initially planned
- Limited regulation of technical specifications in particular for grid connection
- Challenge of transporting electricity generated from renewable energy sources through the transmission system to the country's consumption centres
- There have been seven different ministries in charge of the power sector of Sudan since 1989, often with limited knowledge handover, resulting in confusion and failure to fulfil previous plans.[16]

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1.3.5 Tunisia

Nouri Chtourou, Soukaina Fersi, Emna Omri and Rim Jemli, University of Sfax

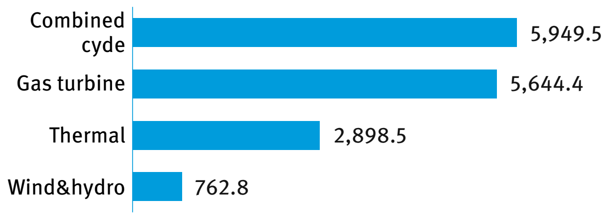
Key facts

Population	11,446,300[1]
Area	155,360 km[2]
Climate	The north of Tunisia benefits from a Mediterranean climate, the centre and the Gulf of Gabes have a semi-arid climate and the rest of the country has a desert arid climate.[2]
Topography	The country is divided into 3 distinct regions. The northern region is characterized by mountains, cork forests and grass lands. The central region is a semi-arid steppe plateau with olive groves. The southern region, which stretches from the Algerian border to the Mediterranean, contains date palm oases and saline lakes. The extreme south of Tunisia merges into the Sahara Desert. The highest point is called Jebel Chambi (1,544 metres), near Kasserine.[2]
Rain pattern	In the north of the country, rainfall is between 400 mm/year and 1,500 mm/year in the far northwest. The central region of the Tunisia receives 200 mm to 400 mm/year, while in the southern regions of the country, rainfall becomes rare, averaging about 50-200 mm/year.[3]
Hydrology	The most important river system in Tunisia, the Medjerda, rises in Algeria and drains into the Gulf of Tunis. Its course has a length of 460 km. It is the only river that flows perennially; other watercourses fill only seasonally. In the central Tunisian steppes, occasional waterways flow southward out of the Dorsale after heavy rains, but they evaporate in salt flats without reaching the sea.[3]

Electricity sector overview

The energy sector in Tunisia is characterized by a steady rise in energy demand and a decrease in the availability of national resources. In 1994, the net import of energy was 2,907.5 GWh. This has been increasing since 1999 and in 2015 the net import of energy was 57,219.6 GWh.[4] Electricity generation rose from 18,249 GWh in 2015 to 18,256 GWh in 2016.[5] Figure 1 shows the repartition of the electricity produced in 2016 by source.

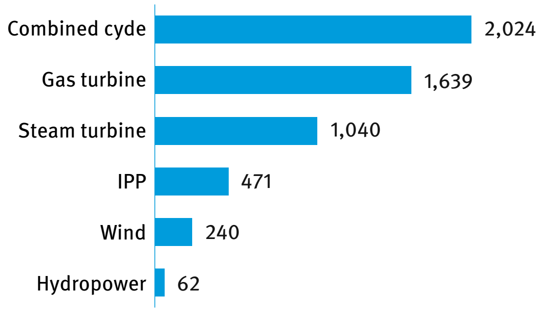
Figure 1.
Annual electricity generation by source in Tunisia (GWh)



Source: STEG[6]

Installed electricity capacity in Tunisia increased from 5,224 MW in 2015 to 5,476 MW in 2016. The energy sector primarily uses natural gas, which accounts for more than 90 per cent of electricity production, so the national generation capacity is essentially composed of steam turbines, gas turbines and combined cycle. The share of wind and hydropower in electricity production is very insignificant compared to the potential of those two resources in Tunisia. Figure 2 shows national installed electricity capacity in 2016 by source.

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



Source: STEG[7]

The continuous volatility of fossil fuel prices and the energy deficit increase has caused many negative economic repercussions, including massive outflows of foreign currency and an increase in public spending. This is because fossil fuels are subsidized by the Government.

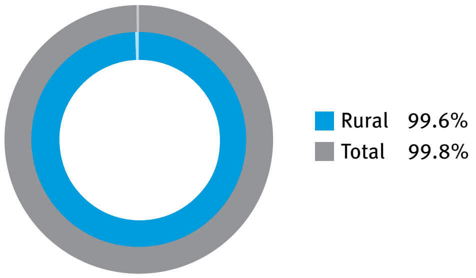
Another feature of the energy sector is the vast amount of conventional energy subsidies. In fact, the budget allocated to energy subsidies has increased from 650 million Tunisian dinars (approximately US$ 282 million) in 2017 to 1.5 billion

Tunisian dinars (approximately US$ 633 million) in 2018.[8] There are many factors which affect the level of subsidies, including deficit of resources, gas prices, the price of imported energy and currency exchange rates.

The dependency of Tunisia on natural gas makes the country vulnerable to technological, market and geopolitical risks. For example, the volume of gas transit from Algeria to Italy has fallen since 2010. This has caused power plants to generate less power, which consequently resulted in a decrease in the tax package attached to the Trans-Tunisian gas pipeline, therefore worsening the energy deficit.

In 2015, the high voltage (HV) electricity transmission network was extended by 231 km, to reach a length of 6,440km, an extension of 3.7 per cent compared to 2014. The medium voltage (MV) and low voltage (LV) lines had a combined extension of 2.6 per cent compared to 2014 (increased by 4,186 km), reaching a length of 165,090 km (56,576 km of medium voltage lines and 108,514 km of low voltage lines).[9] In 2016, the total national electrification rate was 99.8 per cent, whilst the rural electrification rate stood at 99.6 per cent.[10]

Figure 3.
Electrification rate in Tunisia (%)



Source: STEG[10]

The main actor in the electricity sector is the state-owned Tunisian Company of Electricity and Gas (STEG), which is responsible for generation and distribution. The Tunisian electricity market is partially liberalized. Following Decree 1996-1125 (1996) and Law 96-27 (1996), the private generation of electricity is possible through concessions given by state authorities. This also includes off-grid sources.

Energy prices at all levels are set by the Ministry of Industry in collaboration with relevant government agencies such as the General Direction for Energy (DGE), the Tunisian Enterprise of Petroleum Activities (ETAP), the Tunisian Company of Refining Industries (STIR), the Ministry of Commerce and the Ministry of Finance. Energy prices are set at the end of each fiscal year. Prices are influenced by numerous factors, including the international price of crude oil and gas, the financial situation of STEG, ETAP and STIR, as well as the level of government subsidies.

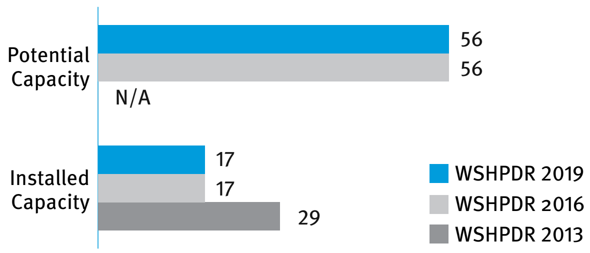
After the STEG's price policies have been approved by the Government, the Ministry of Industry sets consumer gas and electricity prices. Until 2004, STEG's prices reflected approximate production costs, and grants (e.g. rural electrification, or tariffs for certain categories of rural consumers) were fed mainly by cross-subsidies between tariffs.

Electricity tariffs are arranged by time slots for HV, MV and pumping water for agricultural irrigation. There are four time shifts: day, peak, evening and night. Since January 2017, STEG has increased electricity tariffs by 5 per cent. For the category that consumes between 1 and 200 kWh/month of electricity, the price per kWh is 162 millimes (approximately US$ 0.07). The category that consumes between 201 and 300 kWh/month, the price per kWh, is fixed at 198 millimes (approximately US$ 0.09). For the category whose consumption is between 301 and 500 kWh/month, the tariff is 285 millimes (approximately US$ 0.12) for households and 260 millimes (approximately US$ 0.11) for other consumers. Concerning the category for monthly consumption exceeding 500 kWh/month, the price per kWh is set at 350 millimes (approximately US$ 0.15) for households and 295 millimes (approximately US$ 0.13) for other consumers. However, there is an exemption for households consuming between 1 and 50 kWh/month, for which the tariff adopted remains within the limit of 75 millimes (approximately US$ 0.03) per kWh, and also households consuming between 1-100 kWh/month, for which the price kWh is set at 108 millimes (approximately US$ 0.05).[11]

Small hydropower sector overview

For the purposes of this report, the definition of small hydropower (SHP) will be 10 MW or less. The installed capacity of SHP in Tunisia is 16.98 MW, while the potential is estimated to be 55.98 MW indicating that less than 63 per cent has been developed. There has been no change in either installed capacity or estimated potential since the *World Small Hydropower Development Report (WSHPDR)* 2016 (Figure 4).

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



Source: *WSHPDR 2013*,[20] *WSHPDR 2016*,[12] STEG,[13] Saidi, L., and Fnaiech, F.[14]

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

Tunisia has great theoretical hydropower potential, estimated at 1,000 GWh/year in the mid-1990s, but the technically feasible potential is only approximately 250 GWh/year. There is an installed hydropower generation capacity of 67 MW in the country, of which 62 MW is connected to the national grid and around 5 MW of which is isolated. The oldest hydroelectric power plant is located in Nebeur (Kef Governorate, northern Tunisia). Built in 1956, it is a dam with a river reservoir and has a capacity of 13.2 MW.

There are seven hydropower plants in Tunisia. Many of them were built during the period of French colonization and most of them are located in the north-western region. The total installed capacity of these plants is 67 MW with electricity generation between 50-160 GWh.[13] The seven hydropower plants of Tunisia are shown in Table 1.

Table 1.
Hydropower plants in Tunisia

Hydropower plant	*Capacity (MW)*
Sidi-Salem	36.00
Nebeur	13.20
El Aroussia	4.80
Sejnane	0.60
Kessab	0.66
Fernana	8.50+1.20
Bouhertma	1.20+0.62
Total	**66.78**

Source: STEG[13]

The two hydropower plants of Sidi Salem and Nebeur have capacities of 36 MW and 13.2 MW, respectively. Therefore, there are only five SHP plants in Tunisia, at El Aroussia, Sejnane, Kessab, Fernana and Bouhertma. It should be noted that the hydropower plant of Sejnane, with a capacity of 0.6 MW, is not currently in operation. This leaves overall installed capacity standing at 16.98 MW.

The renewable energy (RE) strategy in Tunisia is focused on solar and wind energies, which receive the support of the Government. Little interest is given to hydropower, either from the Government or private investors. This would explain the stagnation of hydropower installed capacity in comparison to other sources of RE in Tunisia.

According to some reports and studies, there is the possibility of constructing nine other SHP plants with capacities ranging from 250 kW to 3 MW. The sites and capacities of these plants are as follows: Barbara (3 MW), Bouhertma (1.2 MW), Sejnane (1 MW), Sidi Saad (1.75 kW), Siliana (850 kW), Bejaoua (750 kW), Khanguet Zezia (650 kW), Nebhana (500 kW) and Medjez el Bab (250 kW). The total capacity of the programme is expected to be 10 MW.[14]

Renewable energy policy

In order to lower dependency on natural gas and reduce the conventional energy subsidies, Tunisia has made an effort since the 1980s to promote RE and energy efficiency. The National Agency for Energy Management was established in 1985, and a second organization, STEG-ER, was established in 2010. The goal of these two organizations is to improve national policy in the field of RE and energy efficiency. In this field, the main activities of STEG-ER are:

- Feasibility studies, technical assistance and supervision of the realization of power plants producing electricity from renewable energy or from co-generation
- Monitoring and supervising RE electricity generation
- Participation in RE electricity production projects
- Audit and energy expertise in the field of RE (study and consultancy services)
- Training in the field of RE[15]

In order to strengthen national RE policy, a Tunisian Solar Plan (TSP) has been established. This incorporates renewable technologies and energy effectiveness according to the Mediterranean Solar Plan view. The TSP aims to increase the share of RE in electricity generation to 30 per cent and to reduce carbon intensity by 41 per cent by 2030.

In addition, the new Law No. 12, of 11 May 2015, on the production of electricity from RE, has been adopted and promulgated. This law aims to promote the development of RE and strengthen electricity supply in Tunisia by encouraging private initiatives and liberalizing the production and export of electricity. This Law allows public enterprises and local authorities to produce electricity from RE and sell it to STEG. In fact, it is based on four main areas: the establishment of a national plan for electricity produced from RE sources, incentives for private sector initiatives, expanding the self-power generation system for local authority consumption and the organization of electricity export activities. However, it should be noted that the distribution of electricity and transport remain exclusively the prerogative of STEG.

In Tunisia, various new programmes have been implemented recently in order to promote the RE sector:

Financial incentives for investments in RE
In accordance with Law No. 2016-71 (of Investment) of 30 September 2016 and Governmental Decree No. 2017-389 of 9 March 2017, investments made in the sector of RE benefit from the following advantages:
- Increase in the added value and competitiveness premium – 15 per cent of the approved investment cost with a ceiling of 1 million dinars (approximately US$ 434,500).
- Regional development premium – this is 15 per cent of the approved investment cost, with a ceiling of 1.5 million dinars (approximately US$ 651,700) for the first group of regional development zones, and 30 per cent of the approved investment cost with a ceiling of 3 million dinars (approximately US$ 1.3 million) for the second group of regional development zones.
- Employment capacity development premium – the State supports contributions made by employers to the social security legal system. These contributions are wages paid to the Tunisian employees recruited for the first time and in a permanent way for the first three years from the date

of entry into effective activity. This duration is extended to 5 years if the project is established in an area of the 1st group of regional development zones and 10 years if the project is located in an area of the 2nd group of regional development zones. [16]

Tax advantages for investments in RE

In accordance with Law No. 2017-18 of 14 February 2017, investments realized in the RE sector have certain tax advantages, such as:

- Tax advantages for regional development – a deduction of the taxable base of income or profit, of physical persons and corporations, made from investments at a regional development level. This deduction, starting from entry into the activity, is for the first five years for the 1st group and for the first ten years for the 2nd group of regional development zones.
- Tax advantages for reinvestment – a tax deduction, limited to income or profit subject to tax, of income or profit reinvested in the subscription to the initial capital or its increase.[16]

The main RE projects that have been realized in Tunisia are in wind and solar energies. In fact, a new solar PV project is under construction in the south of Tunisia. Its installed capacity will be 10 MW and electricity generation will be 17 GWh/year. Several RE projects are planned for the coming years. STEG-ER is planning the development of 26 new wind power projects, at 30 MW each, and 40 solar projects, at 10 MW each, giving a total of 400 MW.[17,18] However, it is often the case that hydropower projects remain in the feasibility study phase, among them the 400 MW pumped storage power station in Oued El Maleh, the mini hydropower plants of Bouhertma and Sejnane, and the 5 MW hydroelectric power plant from Oued Barbara to Oued Mejerda.[19] Although there is no further information on these projects, the likely reason that they remain in feasibility study status is because in Tunisia there is a limited capacity to undertake feasibility studies – detailed studies that would include specifications for the design and cost of schemes, in order to make a meaningful impact on the utilization of SHP sites.

Barriers to small hydropower development

There are barriers common to all RE projects, namely the lack of clear-cut policies, lack of budgetary allocations and absence of long-term financing to ensure price affordability. In addition to these, SHP implementation is hindered by:

- Limited access to appropriate technologies in the mini-, micro- and pico-hydropower categories, which pose specific technical challenges;[12,22]
- Limited infrastructure for manufacturing, installation and operation – an example of this is the capacity to manufacture high-density polyvinyl pipes that can serve as good penstocks for the micro-hydropower schemes. Few countries have these products and as such exploitation of otherwise simple sites has been hampered by this deficiency;[12, 21]
- Limited specialization to undertake feasibility studies – detailed studies that would include specifications for the design and cost of schemes, in order to make a meaningful impact on the utilization of SHP sites;[12, 21]
- High competition with other RE technologies, as well as the maturation of solar and wind technologies;[21]
- Limited commitment on the part of the Government to encourage and promote SHP technologies;[21]
- Limited participation from the private sector.[21]

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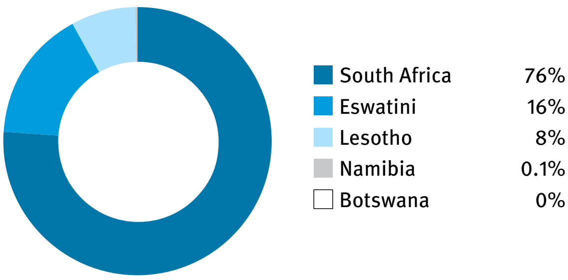
1.4 Southern Africa

Wim Jonker Klunne, Hydro4Africa

Introduction to the region

The region of Southern Africa comprises five countries – Botswana, Namibia, Lesotho, South Africa and Eswatini (formerly Swaziland). The total installed capacity of small hydropower (SHP) up to 10 MW in the region is 50 MW, with most of it located in South Africa (Figure 1). In most of the countries in the region the electrification rate has been increasing in the past years, however it still remains low in Lesotho at 30 per cent. The highest electrification rate is in South Africa, reaching 84 per cent. An overview of the countries of the region is presented in Table 1.

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



Source: *WSHPDR 2019* [3]

The region has various climatic conditions, from tropical to temperate, semi-arid and desert, some of which are more suitable for hydropower than others.

The countries in the region are interconnected through the Southern African Power Pool. Although several initiatives in the region promote renewable energy (RE), including SHP, the region is substantially dependent on coal-generated electricity from South Africa. Lesotho, Namibia and Eswatini produce all or most of their electricity from large-scale hydropower, while South Africa is still mostly coal-dependent.

At the regional level, the Southern African Development Committee (SADC) does coordinate international support for energy development in the region, including RE, and has developed a Renewable Energy & Energy Efficiency Strategy and Action Plan.[4] In October 2018, the SADC Centre for Renewable Energy and Energy Efficiency (SACREEE) was officially launched as a SADC implementation entity to advance the uptake of renewable energy in the region, including small-scale hydropower.

Table 1.
Overview of countries in Southern Africa

Country	*Total Population (million)*	*Rural population (%)*	*National electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Botswana	2.3	31	66	893	3,020	0	0
Eswatini	1.4	79	65	61	171	60	119
Lesotho	2.2	72	30	77	508	76	N/A
Namibia	2.5	51	58	557	1,700	347	1,593
South Africa	56.7	34	84	47,043	237,000	2,184*	3,717
Total	**65.1**	-	-	**48,631**	**242,399**	**2,667**	**5,429**

Source: *WSHPDR 2016*,[2] *WSHPDR 2019*,[3] WB,[5,6] Statistics Botswana,[7] NamPower [8]

Note: *Including pumped-storage hydropower plants

Small hydropower definition

Most countries of the region do not have official definitions for SHP. Therefore, in this report the definition of SHP of plants with a capacity up to 10 MW will be used for these countries (Table 2). In Lesotho, SHP is defined as hydropower plants of up to 10 MW. The current threshold used by South Africa is set at 40 MW. However, a new policy is to decrease this value to 10 MW.

Regional small hydropower overview and renewable energy policy

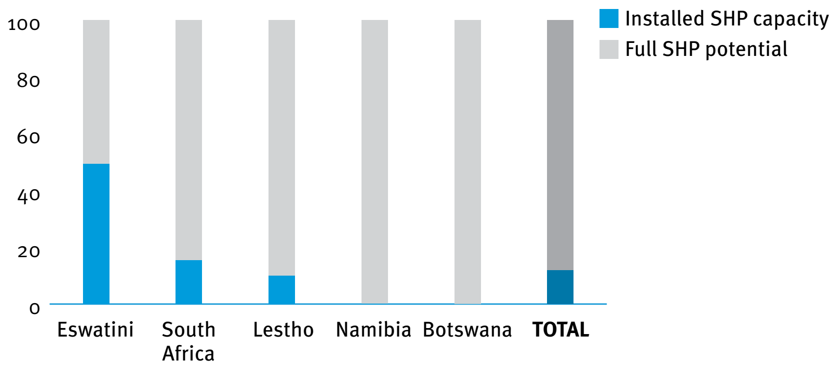
The most significant energy resource in the region is solar energy, with many RE policies identifying it as the most important area for development. Wind power can also be developed in certain countries. Four countries in the region use SHP, with a combined capacity for plants up to 10 MW standing at 50 MW (Table 2). The total known SHP potential up to 10 MW is estimated at 422 MW, of which only 12 per cent has been developed (Figure 2). Compared to the *World Small Hydropower Development Report (WSHPDR) 2016*, the region's installed SHP capacity up to 10 MW has decreased by approximately 20 per cent (Figure 3), which is due to access to more accurate data on the capacities of South Africa and Namibia.

Table 2.
Small hydropower capacities in Southern Africa (local and ICSHP definition) (MW)

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed (<10 MW)*	*Potential (<10 MW)*
Botswana	-	-	-	0.0	1.0
Eswatini	-	-	-	8.2	16.2
Lesotho	up to 10	3.8	38.2	3.8	38.2
Namibia	-	-	-	0.05	120.0
South Africa	up to 40	N/A	N/A	38	247.0
Total		-	-	**50**	**422**

Source: *WSHPDR 2019* [3]

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



Source: *WSHPDR 2019* [3]

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

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

Botswana has a very limited SHP potential, estimated at 1 MW, and is currently not using SHP at all. Solar power is the most important source of RE in the country, with an average daily solar radiation of 6.1 kWh/m^2. Nonetheless, the photovoltaic systems installed in the country have the capacity of 1 MW, accounting for only 0.8 per cent of the country's total capacity.

The first electric lighting system in **Eswatini** was installed with a 42 kW SHP turbine. Since then, the country has had several public and private hydropower plants installed, as well as some industrial installations. The total installed SHP capacity of Eswatini is at 8.21 MW, including one decommissioned plant of 0.5 MW. At the national level a comprehensive resource assessment has been carried out showing that there is at least 8 MW available for further SHP development, with some sites currently being under consideration. Since 2007, Eswatini has had a strategic framework and an action plan for development of renewable energy in the country. The Government seeks to maximize the use of RE, encourage education and training on RE, promote greater awareness of RE and develop accurate data on available RE resources. However, the development in this area has still been relatively slow.

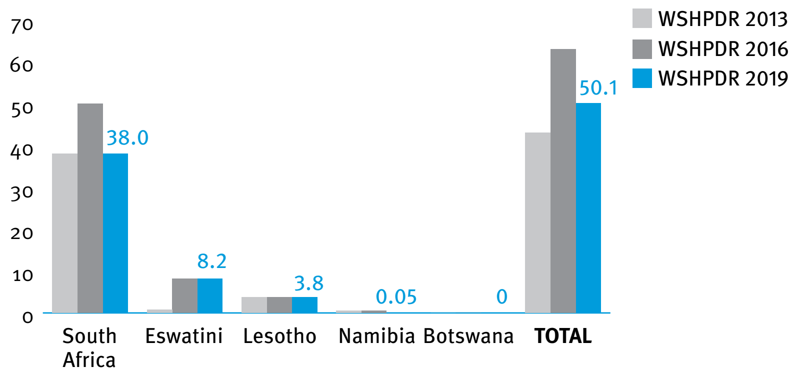
Lesotho has two operational SHP plants of 0.57 MW and 0.18 MW, both owned and operated by the national utility company, the Lesotho Electricity Company. Although there is an untapped potential of approximately 34 MW and some plans exist for the construction of additional SHP capacity, the circumstances do not seem to facilitate swift development of these projects. Nonetheless, the Lesotho Highlands water project does offer opportunities for more hydropower development. Several studies have also been conducted on possible pumped-storage plants. Besides hydropower, Lesotho has identified wind and solar power as potential RE sources. Solar power has been implemented in several schemes with the support of the World Bank, the UNDP and the Global Environment Faculty.

The current installed SHP capacity of **Namibia** is 0.05 MW and the potential is estimated at 120 MW, which includes hundreds of small farm dams around the country, where SHP could be developed. The Namibia Power Corporation, the leading national energy company, set the target of sourcing at least 10 per cent of national energy from renewable sources other than hydropower. It also launched tenders for independent power producers (IPPs) to develop 30 MW of solar power as part of a national programme to commission a total of 94 MW through solar and wind technologies.

South Africa has 38 MW of installed SHP capacity and a proven potential of 247 MW (up to 10 MW). SHP played an important role in the historic electrification of the country, but was not developed for decades until recently. The Integrated Resource Plan of South Africa outlines the expected electricity mix in the country until 2030, including the envisaged role of hydropower. The Government has implemented this plan through the Renewable Energy Independent Power Producers Procurement Programme (REIPPPP), which aims to add 17,800 MW of RE (solar and wind) to the country's installed capacity, as well as 75 MW from SHP. This programme has already resulted in the installation of three SHP systems (19.1 MW) contracted by the Government for feeding into the national grid. Parallel to this, a number of privately-owned systems have been developed purely for private consumption. Traditionally, the country's energy policy has focused on large-scale, grid-connected RE projects. However, with the national energy regulator, NERSA, preparing guidelines and policies targeting small-scale plants, future activities in the area of small power plant development, including SHP, will be facilitated. The future development of SHP in South Africa will be based both on IPP-developed plants feeding into the national electricity system and small-scale plants for private use not feeding into the grid. Currently, no support is available for stand-alone systems for rural electrification purposes, although the Government is currently reviewing its rural electrification strategy.

A **feed-in tariff (FIT)** scheme was in place in South Africa until 2011, but was replaced by the Renewable Energy Independent Power Producers Procurement Programme (REIPPPP). Namibia has a functioning FIT programme. However this focuses mainly on solar and wind power. The Government of Lesotho has been considering the introduction of FITs.

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



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

Note: *WSHPDR* stands for *World Small Hydropower Development Report.* For all countries, data is for SHP up to 10 MW.

Barriers to small hydropower development

The current electricity situation in the region, which combines limited availability of electricity with increasing prices, does create an enabling environment for renewable energy technologies. The general limiting factors for SHP in the region include vague legislative frameworks, unfamiliarity with the technology, a lack of suitable business models and in some cases conflicts over access to water and land.

For **Botswana** and **Namibia**, the key barrier is the fact that there is very limited potential for hydropower. In Botswana, there are currently no hydropower plants in operation in the country, and no known plans towards hydropower generation. Due to scarce water resources, Namibia is dependent on the neighbouring countries for its water supply, and climate change is expected to exacerbate the unpredictability of the hydrological regime. Furthermore, in Namibia there is a concern among the indigenous population that the hydropower industry might impact their way of life, which causes conflicts over internal land use.

Contrastingly, the conditions for the development of SHP in **Lesotho** can be described as conducive, in particular, due to the availability of hydropower resources. However, in practice, SHP development has been complicated by the lack of infrastructure, fragmented institutional responsibilities, lack of integrated planning and the fact that the rural population often cannot afford to pay for it.

Similarly, in **Eswatini**, there is some hydropower potential, which has been well documented and could be developed with the support of the legal framework that allows for the operation of independent power producers. However, limited private investments into the sector, increasing electricity prices, the reduced reliability of the national grid and a lack of data on potential SHP sites for refurbishment have made up until now the development of SHP difficult.

South Africa possesses a significant SHP potential. However, more extensive development is hampered by the complicated and lengthy processes associated with completing an Environmental Impact Assessment and obtaining licences and permits. There are also issues with regard to access to and permission of crossing private or state land.

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1.4.1 Botswana

Ditiro Benson Moalafhi, University of Botswana

Key facts

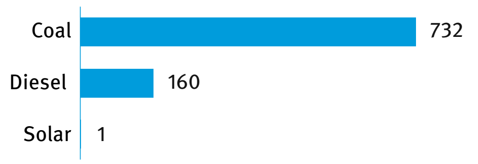
Population	2,250,260[1]
Area	581,730 km[2]
Climate	Botswana's climate is arid to semi-arid, influenced by the size and shape of the southernmost finger-like tip of the African continent and latitudinal position.[2,3,4] Daytime summer temperatures normally stay around 35 °C, but can even reach 40 °C. On the other hand, winter temperatures range between 3 °C and 24 °C.
Topography	Botswana lies on the Southern African Plateau, with an average elevation of 1,000 meters (3,300 feet) above sea level.[5] The country is largely flat and surrounded by higher plateaus of Zambia to the north, Zimbabwe to the northeast, South Africa to the southeast and south and Namibia to the west, giving it a 'saucer-like' physiography.[6] The Kalahari, with its dry sand, dominates the country, but areas to the east have varying geography and soil types. Three-quarters of the land surface is in fact covered by the Kalahari sands, which fill the basin to a depth of up to several hundred meters. The lowest point in Botswana is at the confluence of the Limpopo and Shashe rivers, at an altitude of 537 metres, while the highest point is found at the Otse Hill in the southeast, at 1,491 metres.[7]
Rain pattern	Rainfall over Botswana is mainly caused by instabilities associated with tropical cyclones and movements of the inter-tropical convergence zone (ITCZ). The geographical location of the country in the interior of the southern African sub-continental landmass and at the southernmost tip of the ITCZ gives it one rainy season – during the summer months (November to April).[6] Annual rainfall ranges from highest of 650 mm from restricted north-eastern parts of the country to the lowest of around 250 mm to the extreme south-western parts of the country. Over the whole country, rainfall averages around 450 mm per annum. Previous studies have indicated that over 90 per cent of the rainfall occurs in the summer months. At times, 70 per cent to 90 per cent of the annual total rainfall may occur in only one month. Rainfall tends to occur in wet spells lasting several days at a time. These wet spells are interspersed with lengthy dry spells. Botswana's rainfall is characterized by high variability, which has implications for water resources and related enterprises.[8]
Hydrology	All the main river systems of the country originate from outside the country. The headwaters of the Limpopo, for example, are in the vicinity of Johannesburg in South Africa and many of its main tributaries drain northern Transvaal.[2] In the north east, the Shashe River, a tributary of the Limpopo that forms part of the border between Botswana and Zimbabwe, receives tributary inflows from Zimbabwe.[6] In the north-eastern Botswana, the Okavango river system receives over 90 per cent of its flows from Angola through its two main tributaries. The Okavango river dissipates itself into the Okavango Delta, an area of 12,000 km[2] of permanent and seasonal swamps after entering Botswana.[6] The Kwando-Linyanti-Chobe system, which is a tributary of the Zambezi (along which Botswana has a brief common border for a few hundred meters with Zambia) receives virtually all of its flows within Angola. In the south the Molopo River, which forms the boarder with South Africa and is a minor tributary of The Orange River, receives most of its very occasional flows from its tributaries in Northern Cape Province.[6] The Makgadikgadi Pans are also much too dependent on the Nata River, whose catchment largely falls in Zimbabwe.

Electricity sector overview

The Department of Energy Affairs (EAD) within the Ministry of Mineral Resources, Green Technology and Energy Security (MMRGTES), formerly the Ministry of Minerals, Energy and Water Resources (MMEWR), leads the country's national energy policy. MMRGTES, through Botswana Power Corporation (BPC), is the main decision maker for power generation, transmission and distribution.

Botswana's energy capacity is thermal, produced mostly in coal-fired plants, with a few small diesel generators in rural areas. From the year 1989, the Government parastatal Botswana Power Corporation (BPC), operated a 132 MW coal fired power plant facility (Morupule A) with additional electricity needs (about 20 per cent) met through imports from South Africa. Capacity of the facility, however, dropped to 30 per cent in 2012 and the station was closed in 2016 for the rehabilitation and upgrading additional capacity. As well as the closure of Morupule A for refurbishment, a new coal fired power plant (Morupule B), which had been under construction since the year 2006, has slowly come into operation. Morupule B has an installed capacity of 600 MW, although generation is currently at 450 MW, compared to a national demand of 550 MW. The difference is met by importing up to 150 MW from South Africa, but does not prevent load shedding. In 2013, two emergency diesel facilities, 70 MW at Matshelagabedi and 90 MW at Orapa, were also installed to avoid such outages. This brings installed capacity to 893 MW, with an operational capacity of 610 MW. Coal and diesel installed capacity stands at 732 MW and 160 MW respectively (Figure 1). Morupule B also started expansion in 2016 in order to add another 300 MW by 2020. Morupule A is expected to be fully operational by the end of 2018 with 130 MW installed capacity. Based on 2013 data, Botswana's national electrification rate reached 66 per cent (54 per cent in rural areas, 65 per cent in urban ones). One million people in Botswana still lack access to electricity.[9]

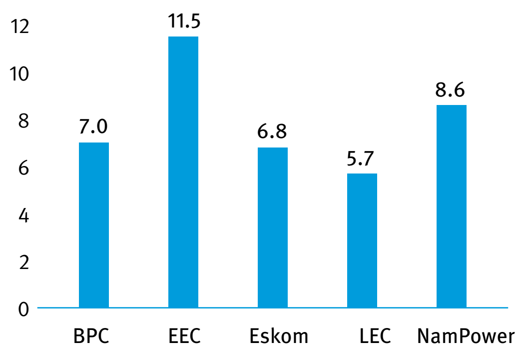
Figure 1.
Installed electricity capacity by source in Botswana (MW)



Source: USAID,[10] IEA[16]

In 2017, electricity tariffs in Botswana were US$ 0.0706 for monthly consumption up to 200 kWh and US$ 0.0981 for consumption exceeding 200 kWh per month.[11] The country has one of the lowest tariffs in the region (Figure 2), mainly due to subsidies by the Government. Botswana is a member of the Southern African Development Community (SADC), which has prioritized the implementation of cross-border transmission projects in an effort to link the power systems of all SADC Member States.

Figure 2.
Average electricity tariffs in the region (US$ cents/kWh)



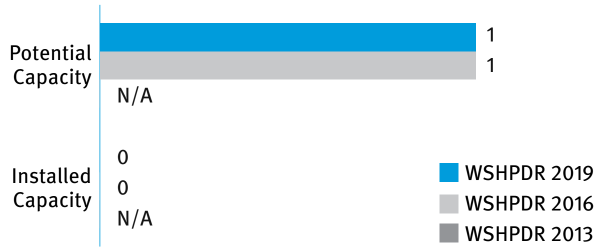
Source: SADC[12]

Note: BPC-Botswana; Eskom-South Africa; LEC-Lesotho; NamPower-Namibia; EEC-Eswatini

Small hydropower sector overview

There are no hydropower plants in operation. Due to the severe water shortages, it is unlikely that any hydropower projects will be developed in the near future. However, there is a potential for development of 1 MW, located in the north of the country (Figure 3).[14]

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



Source: *WSHPDR 2016*,[15] Jonker Klunne[14]

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

Renewable energy policy

Ministry of Mineral Resources, Green Technology and Energy Security (MMRGTES) is in charge of the energy sector. The energy regulator is the Botswana Energy and Water Regulatory Agency (BEWRA). The electricity sector is vertically integrated and is managed by Botswana Power Corporation. On a regional level, the country is a member of the Southern Africa Power Pool. The legal framework is provided by the Electricity Supply Act 2007. There is a national energy policy, which aims to provide 80 per cent access to the country as a whole and 60 per cent access in rural areas through the increased use of renewable energy. This would reduce the dependence on coal, which is a greenhouse gas emitter.[13] The National Energy Policy is also designed to underpin self-sufficiency and to orientate the energy sector towards exports. The National Energy Policy recognises the need for increased utilisation of Botswana's energy resources, namely coal, coal bed methane and renewable energy.

Improving energy security in terms of energy supply is one of Botswana's policy objectives. Botswana has one of the highest levels of solar insolation worldwide, with a direct normal irradiation (DNI) of 3,000 kwh/m2/year.[13] It is estimated that Botswana could meet its current electricity consumption by using less than 1 per cent of the country's area for solar energy. The first solar power generation plant opened in September 2012 and solar is currently used for domestic water heating, home lighting, electricity supply for telecommunications equipment and in rural areas where access to conventional electricity is difficult. The potential for business in the manufacture and assembly of solar energy equipment is huge.

Barriers to small hydropower development

There are currently no hydropower plants in operation in the country, and no known plans towards hydropower generation. Networked micro-hydropower could still be a possibility despite the country's flat topography and limited water in the country's river systems, conditions which do not favour hydropower generation. Feasibility studies towards nested micro-power generation could still be a possibility.

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1.4.2 Eswatini

Wim Jonker Klunne, Hydro4Africa

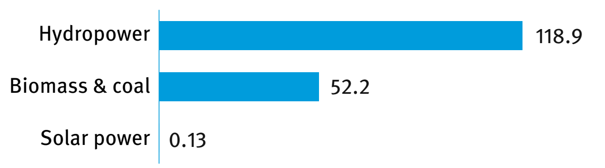
Key Facts

Population	1,367,250[1]
Area	17,364 km[2]
Climate	The climate is temperate in the west, but temperatures can reach 40 °C in the eastern Lowveld region during the summer months, between October and March. In the capital city, Mbabane, the average temperature is 20 °C in January and 12 °C in July.[3,10]
Topography	The Kingdom of Eswatini (formerly Swaziland) is a landlocked country in Southern Africa, bordered to the north, south and west by South Africa, and to the east by Mozambique. Eswatini is a small country of no more than 200 km north to south and 130 km east to west. The western half is mountainous, descending to the Lowveld region to the east. The eastern border with Mozambique and South Africa is dominated by the escarpment of the Lebombo Mountains. The highest point is Emlembe at 1,862 metres.[3,10]
Rainfall pattern	Rainfall occurs mainly in the summer months, between October and March. Average annual rainfall may reach 2,000 mm in the western highveld, but decreases toward east with the lowveld averaging between 500 mm and 900 mm.[3,10]
Hydrology	Major perennial rivers, which have their sources in South Africa, flow through the country to the Indian Ocean. They are the Lomati, the Komati, the Umbuluzi, and the Usutu. The Usutu has the largest catchment in the country, with three main tributaries, the Usushwana, the Ngwempisi, and the Mkhondvo.[4,10]

Electricity sector overview

The Eswatini electricity grid is being supplied by the Eswatini Electricity Company (EEC; formerly the Swaziland Electricity Company, SEC) through 4 hydropower stations, the Ubombo Sugar Limited (biomass supplemented by coal) and the Wundersight's Buckswood 100 kW solar PV plant. In addition, there are several private self-generating plants owned by the industrial sector. The local generation is augmented by imports through the Southern African Power Pool (SAPP), with South African Electricity Public Utility (ESKOM) as the major source of electricity. The total electricity generated in the country reached 171,213 MWh at the end of 2016. Eswatini is still highly reliant on imports, with approximately 1,045,980 MWh electricity imported.[5] Figure 1 below offers more information on the electricity generation by source.

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

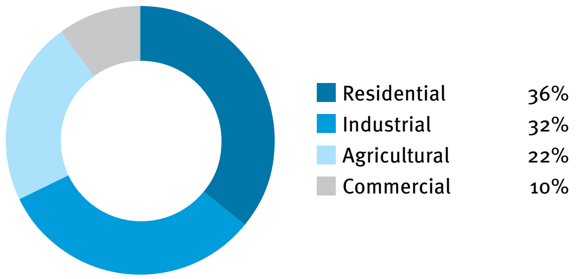


Source: EEC[5]

The four hydropower stations of EEC have a total installed capacity of 60.4 MW and contributed 9.6 per cent to the electricity system (imports were also considered) in the financial year 2016/2017. This figure was down by 3.3 per cent points in comparison to the previous year, due to the severe drought. The EEC hydropower stations are in the Usuthu River Basin catchment (Ezulwini, Edwaleni and Maguduza stations) and in the Komati Basis system (Maguga dam). Both catchment areas were affected by drought during the last year.[5]

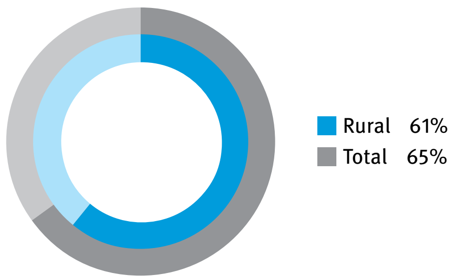
The industrial and residential sectors dominated consumption, with 32 and 36 per cent of the total, respectively (Figure 2). The overall electrification rate is estimated at 65 per cent, with approximately 82 per cent of the urban areas and 61 per cent of the rural areas electrified.[20] Biomass, especially wood fuel, constitutes approximately 90 per cent of the total energy consumed and is still dominant in cooking and heating in rural areas. Biomass is not only the major fuel in households, but also the major source of electricity self-generation in the sugar, pulp and saw mill industries.

Figure 2.
Electricity consumption by sector in Eswatini (%)



Source: EEC[5]

Figure 3.
Electrification rate in Eswatini (%)



Source: WB[20]

As of 1 April 2018, the consumer tariffs ranged from 0.9194 Swazi Lilangeni (US$ 0.074) per kWh to 2.4023 Swazi Lilangeni (US$ 0.192) per kWh (Table 1).[7]

Table 1.
Consumer tariffs in Eswatini by type for 2018/2019

Tariff type	*Facility charge Swazi Lilangeni (US$) per month*	*Energy charge Swazi Lilangeni (US$) per kWh*	*Demand charge Swazi Lilangeni (US$) per kVA*	*Access charge Swazi Lilangeni (US$) per kVA*
Life Line		1.6527 (0.132)		
Domestic		1.7500 (0.140)		
General Purpose	207.43 (16.59)	2.4024 (0.192)		
Small Commercial - Prepayment	207.43 (16.59)	2.4024 (0.192)		
Small Commercial - Credit Meter	414.85 (33.19)	2.4024 (0.192)		
Small Holder Irrigation	1837.99 (126.76)	0.9194 (0.074)	146.73 (11.74)	49.55 (3.96)
Large Commercial and Industrial	2162.33 (172.98)	1.0795 (0.086)	171.44 (13.72)	58.31 (4.66)
Large Irrigation	2162.33 (172.98)	1.0795 (0.086)	149.63 (11.97)	58.31 (4.66)

Source: EEC7

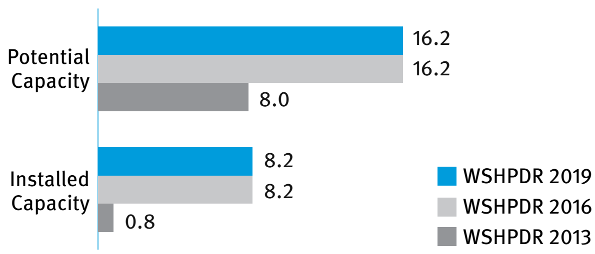
Eswatini's power is supplied and distributed by the Eswatini Electricity Company (EEC), which was established in 2007 as the Swaziland Electricity Company (SEC) by the Swaziland Electricity Company Act of 2007. EEC currently operates as a monopoly with regards to the import, distribution and supply of electricity via the national power grid and owns the majority of the country's power stations. There are also a number of private power stations. A substantial amount (almost 25 per cent) of the energy used in the Kingdom is supplied by self-generators. A reform of the energy sector has been undertaken to reduce the monopoly of the utility (change from a board to a company in 2007), establish a regulatory body and preserve the state company as a more disciplined corporate entity.[6] The following powers and functions have been given to the Eswatini Energy Regulatory Authority (ESERA; formerly the Swaziland Energy Regulatory Authority, SERA):

- Receive and process applications for the licences, and modify/vary the licences;
- Approve tariffs, prices, charges and terms and conditions of operating a licence;
- Monitor the performance and the efficiency of licensed operators.

Small hydropower sector overview

There is no official definition for small hydropower in Eswatini however this report assumes a definition of plants less than 10 MW. The installed capacity is currently 8.205 MW including the decommissioned but still technically operational 0.5 MW plants at Mbabane.[8,10] Additional potential capacity is estimated to be at least 8 MW indicating that more than 50 per cent has been developed so far.[10,11] In comparison to data from the 2016 *World Small Hydropower Development Report* both the installed and potential capacities have remained the same.[9]

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



Source: Jonker Klunne,[8] *WSHPDR 2013*,[9] *WSHPDR 2016*,[10] Knight Piésold Consulting[11]

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

The first electric light to light up the night in Eswatini was installed at Mlilwane with a 52.5 kVA hydro-turbine operated by James Weighton Reilly to separate tin from iron at the Mlilwane Tin Mine. An electrical extension brought light to the farm house (which is now Reilly's Rock Hilltop Lodge). Reilly later installed this plant on the Mbabane River, below where the Swazi Inn was later built, to supply Mbabane with light. Since then several public and private hydro plants have been installed in the country, as well as hydraulic ram pumps to provide water for the steam locomotives at the Ngwenya mine.[10]

Currently, only six hydropower stations are operational in the country, three of which have capacities of less than 10 MW (Table 2).[8,10] EEC operates the grid connected to the Ezulwini (20 MW), Maguga (19.5 MW) Edwaleni (15 MW) and Maguduza (5.6 MW) installations. The Mbabane station of 500 kW was decommissioned by EEC (then SEC) in December 2010 as it was no longer able to operate profitably.[12] Two private small hydropower plants are also in operation: the 800 kW system of Swaziland Plantations and the 1.305 MW station of Ubumbo Sugar in Big Bend.[8,9,13]

Table 2.
Current hydropower plants in Eswatini

Station	*Total capacity (MW)*	*Number of turbines*	*Turbine capacity (kW)*	*Year of construction*	*Owner*
Ezulwini	20	2	10,000	1985	SEC
Maguga	19.5	2	9,600	2006	SEC
Edwaleni	15	4 + 1	2,500 + 5,000	1969	SEC
Maguduza	5.6	1	5,600	1969	SEC
Ubumbu Sugar	1.305	2	728	1986	Ubumbu Sugar
Swaziland Plantations	0.8	2	400	1952	Swaziland Plantations
Mbabane	0.5	2	250	1954	SEC [decommissioned]
Total	**62.705**	**16**	**34,078**		

Source: Jonker Klunne,[8] *WSHPDR 2016*[10]

Both the Edwaleni and Maguduza plants feed from the Greater and the Little Usutu rivers (see Figure 5). In the mid to late 1980s EEC encountered serious problems with siltation in the canal and pondage system to such an extent that an island had formed. This not only reduced the stations' capacity to provide peak power but also caused severe wear on the turbines.[10,14] Currently the stations are free of siltation problems.

The Edwaleni station does also comprise of three sets of diesel generation facilities (2x4.5 MW + 1x0.5 MW), however these are seldom utilised by SEC because of the high costs involved.

The hydropower plant of Swaziland Plantations was initially commissioned in 1952 and was built to provide for the power needs of the town of Piggs Peak. The water is taken from the river and stored in a 35 meter high dam, before being fed into a 1.75 metre diameter, 300 meter long tunnel, which is then connected to the penstock. The head is 76.2 metres. The two 400 kW Francis turbines are designed to take a water flow of 0.8 m^3/sec and have an efficiency of approximately 85 per cent (when running at full capacity). They are each connected to a three phase 415 kVA alternator. The alternators feed into an 800 kVA transformer which is synchronised to the EEC system and feeds a 16 km, 11 kV line direct to the sawmill. During summer, when there is an abundance of water, the plant can satisfy approximately 90 per cent of the company's power needs.[10,13] Current operations are highly dependent on water availability, with approximately a quarter of summer production levels possible in the winter, dry season.

The 1.305 MW hydropower station on the Great Usuthu river was commissioned in 1986 and consists of two 728 kW Ossberger turbines. The station provides power to the sugar processing facilities in Big Bend.[8]

A joint 1987 United Nations Development Programme (UNDP) and Energy Sector Management Assistance Programme (ESMAP) study on the energy sector in Eswatini identified a total of approximately 1 MW of non-utility hydropower generation capacity in the country.[14] The latest full study on hydropower potential in Eswatini however was carried out by Knight Piesold Consulting in 2001. The study showed that there are a number of potential micro (<0.1 MW), mini (0.1–2.0 MW) and small (2–10 MW) hydropower sites with an available potential of approximately 8 MW.[11] As part of its objective to expand the hydropower sector, the Ministry of Natural Resources and Energy (MNRE) has, based on the work of Knight Piesold Consulting, built a database of potential sites. This initially identified 35 candidates, ranging from 32 kW to 1.5 MW. This was further reduced to 26, based on their potential for the electricity generation. Four have been identified as viable schemes and are being promoted by MNRE. These are Lusushwana River (300 kW), Mpuluzi River (155 kW), Usutu River (490 kW) and Mbuluzi River (120 kW minimum).[15]

Several studies have been undertaken to estimate Eswatini's total hydropower potential. In 1970, the UNDP financed a study by Engineering and Power Development Consultants which identified 21 possible sites for hydropower schemes.[14] Based on existing information, the Environmental Centre for Swaziland estimates a gross theoretical potential of 440 MW and a technically exploitable potential of 110 MW, of which 61 MW is economically exploitable.[9,10]

Feasibility studies are currently ongoing for the Ngwempisi cascading scheme. The scheme is expected to have a total installed capacity of 120 MW over three different sites. Furthermore. at least one owner of an old defunct 50 kW hydropower plant just outside Mbabane is considering rehabilitation.[10,16]

In addition, T-Colle Investments of Mbabane is looking to build a 5 million Swazi Lilangeni (US$ 575,000) hydropower plant capable of generating 360 kW of electricity on a canal in the central Manzini region. The firm will charge SEC 0.70 Swazi Lilangeni (US$ 0.081) per kWh for the first three years of production.[10, 17]

Renewable energy policy

In 2007, the Ministry of Natural Resources and Energy formulated a strategic framework and action plan with the aims of:

- Establishing a centre for demonstration and education on renewable energy and sustainable energy;
- Encouraging and enhancing, where applicable, topics on renewable energy and energy in general in educational and training curricula;
- Maximizing the use of the renewable energy technologies wherever they are viable;
- Promoting greater understanding and awareness of the renewable energy resources and the associated technologies;
- Developing and maintaining accurate renewable energy resource data and make it available to all, in order to make informed policy decisions regarding the sustainable energy use and supply;
- Developing woodlots in areas where there is an acute fuel wood shortage.[10,18]

At the Global Energy Ministerial Dialogue of the SE4ALL forum in New York in May 2015, Mrs Winnie T. Steward, Acting Principal Secretary of Natural Resources and Energy, announced that 'the private sector has committed to research and power generation from biomass and hydropower by 2018' however the implementation modality of this is unclear.[10,19]

Barriers to small hydropower development

The hydropower resources of Eswatini have been well documented, and with the 2007 reforms of Eswatini's electricity sector, the legal framework for the introduction of independent power producers has been created.[10] However up until now multiple barriers have made the development of small hydropower facilities difficult. Some of the most noteworthy barriers are outlined below.

- Limited private sector investment, although renewed interest in hydropower as an energy source, as indicated through the recent studies about the Ngwempisi cascading system and the Lower Maguduza plant, do indicate that new developments may progress more positively in the future.
- Increasing electricity prices and the reduced reliability of the national grid have also resulted in increased interest in rehabilitation of the old defunct hydropower plants. Although no good overview exists of possible sites for the refurbishment, it can be expected that a number of sites will be economically feasible to rehabilitate.[10]

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1.4.3 Lesotho

Wim Jonker Klunne, Hydro4Africa

Key facts

Population	2,233,339[1]
Area	30,360 km[2]
Climate	A temperate climate with cool to cold winters and hot, wet summers. The maximum temperature can exceed 30 °C in the lowlands in January, whereas in the mountains the temperature can fall down to –20 °C in winter.[2]
Topography	Lesotho is completely surrounded by the Republic of South Africa. It is also the only country in the world entirely situated above 1,000 metres in altitude. Approximately one-quarter of the land area is represented by lowlands located in the west, which vary in height from 1,500 to 1,600 metres above sea level. The remaining three-quarters are highlands reaching 3,482 metres at Thabana-Ntlenyana in the Maluti Range. The mountain ranges run from north to south, while the central ranges, the Maluti, are spurs of the main Drakensberg, which they join in the north, forming a high plateau lying at 2,700 to 3,400 metres.[3]
Rain pattern	Rainfall is seasonally distributed, with up to 85 per cent of the total received from October through April. Average annual precipitation is 788 mm, varying from 300 mm in the western lowlands to 1,600 mm in the north-eastern highlands.[2]
Hydrology	Two of the largest rivers in Southern Africa, the Orange (Senqu) River and the Tugela River, and tributaries of the Caledon River, have their source in the northern region of Lesotho. The country is entirely located within the Orange River basin, with the Orange draining two-thirds of the country and its tributaries the Makhaleng and the Caladon covering the rest.[2,3]

Electricity sector overview

Lesotho does not have any proven domestic reserves of oil, coal or natural gas, and heavily depends on biomass fuels in the forms of wood, shrubs, animals dung, and agricultural residues to meet the energy needs of the majority of the population. The other fuels consumed in significant quantities are mineral coal, liquefied petroleum gas (LPG) and paraffin.[4]

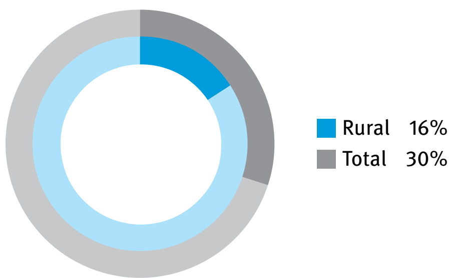
Figure 1.
Installed electricity capacity by source in Lesotho (MW)

Source: Senatla et al.,[5] Department of Energy[7]

The electricity sector is relatively small with an installed capacity of only 77 MW (Figure 1).[5,7] This mainly comes from the 72 MW 'Muela hydropower plant linked to and managed by the Lesotho Highlands Development Authority water scheme to provide water to South Africa. Peak demand has been seen to reach 140 MW, forcing the Government to meet the deficit through imports from Mozambique and South Africa. In 2016, Lesotho generated 507.7 GWh of electricity and imported an additional 372.6 GWh from ESKOM of South Africa and EDM of Mozambique. When electricity demand is low, Lesotho exports excess electricity produced by 'Muela hydropower plant to ESKOM, due to the country's lack of electricity storage capacity. In 2016, Lesotho exported 2.6 GWh of electricity.[4]

Nationwide, only approximately 30 per cent of households have access to electricity. Electricity access rates are 66 per cent for urban households and 16 per cent for rural households (Figure 2).[6]

Figure 2.
Access to electricity in Lesotho (%)



Source: World Bank[6]

Besides hydropower, Lesotho possesses significant resources of other renewable energy sources. In preparation of the recent Scaling up Renewable Energy Programme (SREP)

Investment Plan for Lesotho, the Government of Lesotho carried out a renewable energy resource assessment. Table 1 provides an overview of the potential generation capacity of the different renewable energy technologies.[7]

Table 1.
Potentials for the development of renewable energy technologies in Lesotho

Technology	*Technical potential (MW)*
Utility-scale wind	2,077
Utility-scale solar PV	118
Micro-solar technologies	38
Small-scale hydropower	36
Solar micro-grids	31
Waste to energy	10
Solar home systems	1.2
Floating micro-hydropower	0.5
Total	**2,311.7**

Source: Department of Energy[7]

The electricity supply industry in Lesotho is regulated by the Lesotho Electricity and Water Authority (LEWA). LEWA is an independent regulator responsible for issuing licences, approving electricity tariffs, setting and monitoring the quality of supply and service standards, and resolving disputes between suppliers and customers. LEWA has the authority to regulate all aspects of the industry, including the generation, transmission, distribution, supply, import, and export of electricity.[8]

Electricity is supplied by the Lesotho Electricity Company (LEC). LEC is a parastatal entity established under the Electricity Act 7 of 1969 and is empowered to distribute, transmit, and supply electricity. In 2000, the Lesotho Utilities Sector Reform (LURP) unsuccessfully attempted to privatize LEC and to date the utility remains state-owned. The Lesotho Highlands Water Development Authority (LHWDA) is the agency responsible for the electricity generation from the 'Muela hydropower plant. The roles and responsibilities of these two bodies are set out in the 1993 Policy on the LHWDA/LEC interface.[7]

Table 2.
LEC electricity tariffs 2017/2018

Customer categories	*Final electricity price LSL (US$) per kWh*	*Percentage increase vs. 2016/2017 rates (%)*
Industrial high-voltage	0.2484 (0.017)	2.7
Industrial low-voltage	0.2684 (0.018)	2.8
Commercial high-voltage	0.2484 (0.017)	2.7
Commercial low-voltage	0.2684 (0.018)	2.8
General purpose	1.5995 (0.107)	3.5
Domestic	1.4240 (0.095)	3.4
Street lighting	0.8417 (0.056)	3.3

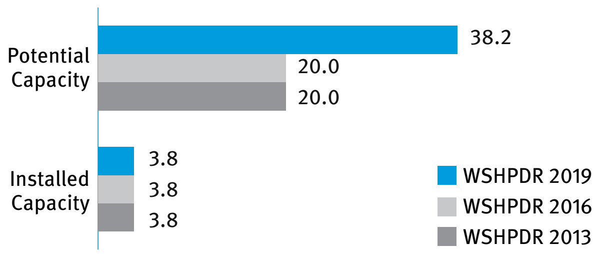
Source: LEWA[9]

The 2017/2018 electricity tariffs for LEC are set by LEWA as shown in Table 2. The final electricity price includes a customer levy of LSL 0.0423 (US$ 0.003) per kWh as well as a rural electrification levy of SLS 0.020 (US$ 0.001) per kWh for large customers and SLS 0.035 (US$ 0.002) per kWh for other customers.[9]

Small hydropower sector overview

Small hydropower (SHP) is defined in Lesotho as hydropower plants with capacity up to 10 MW.[7] As of 2018, the installed capacity of SHP plants was 3.82 MW, while the potential was estimated at approximately 38 MW.[7,10] Compared to the results of *the World Small Hydropower Development Report (WSHPDR) 2016*, the installed capacity remained unchanged, while the potential almost doubled based on the most recent assessment by the Department of Energy (Figure 3).

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



Source: Department of Energy,[7] Jonker Klunne,[10] *WSHPDR 2016*,[11] *WSHPDR 2013*[12]

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

There are five small-scale hydropower plants in Lesotho – Mantsonyane (2 MW), Tlokoeng (670 kW), Katse (570 kW), Tsoelike (400 kW), and Semonkong (180 kW). However, out of these five, only the Katse and Semonkong plants are currently operational.[10]

The Tsoelike hydropower plant is a 400 kW run-of-the-river installation that was constructed to serve the town of Qacha's Nek in the south of Lesotho, close to the border with South Africa. It was commissioned on 5 February 1990 as a part of French development assistance to Lesotho. The plant consists of two Francis hydropower turbine generation units, supplemented by a 200 kVA diesel generator set located on a ledge next to the power plant and a 320 kVA set at the town of Qacha's Nek. Qacha's Nek previously had an isolated system, but has been connected to the South African ESKOM grid since 1997. This cross-border connection has enabled LEC to decommission the plant as it was developing serious technical and siltation problems due to the design of the plant allowing silt to enter the system.

Tlokoeng is a 570 kW hydropower plant in the eastern part of the country, built with French development aid to serve the town of Mokhotlong. The plant has two Francis turbines of 460 kW and 210 kW capacity, augmented by two diesel generator sets as backup – one diesel set at the plant itself (200 kVA) and another at Mokhotlong town of 500 kVA. The plant was commissioned in February 1990 and over its operational life provided on average 27 per cent of the electricity demand of Mokhotlong, ranging from a low of 2 per cent in 1999 to a maximum of 47 per cent in 2000.[13] Originally designed for cyclic storage, equivalent for 27 hours output at full load, due to the siltation of the storage reservoir it effectively turned into a run-of-river plant. The plant is located on the Khubelu River and has seen a history of technical problems related to the bearing failures and exciter problems, as well as flooding in 1996. It was decommissioned in November 2002 when the 33 kV transmission line from the Letseng diamond mine reached the town of Mokhotlong. Since then plans have been tabled to use the plant for peak lobbing and/or operation as an independent power producer (IPP), but no concrete steps have been taken to this effect. The difficult access situation and limited availability of spare parts for the original French equipment have inhibited the development of the site.

The Mantsony'ane hydropower plant was financed by a grant from Norway and handed over to LEC on February 6, 1989. It is located on the Mantsony'ane River in central Lesotho and is feeding the LEC grid through the Mantsony'ane substation on the 33 kV line Mazenod - Taba Tseka. The plant can operate on an isolated network if required, but the main operational strategy has been daily peak lopping. The plant is equipped with two Francis turbines of 1,500 kW and 500 kW, coupled to a 1,900 kVA and a 650 kVA generators, respectively. It features a storage reservoir on the river and an unlined 655 metre long tunnel from the intake to the rock cavern power house. The design head is 35.5 metres. The power plant was flooded with water in November 2006 and was out of operation for a couple of years. It was later rehabilitated as part of the African Development Bank's "Lesotho Electricity Supply Project", but has been out of operation since October 2016 due to technical faults.[14,15,16]

The Katse Dam, a concrete arch dam on the Malibamat'so River, is the second largest dam in Africa and is part of the Lesotho Highlands Water Project, which is planned to include five large dams in remote rural areas. Although the main purpose of the Katse Dam is water storage and diversion, a mini-hydropower plant is included. The plant is located 123 metres below the spillway level of the Katse Dam and consists of a horizontal Francis turbine and an 800 kVA synchronous generator. Since its commissioning in August 2000, the plant has been run in isolation from the LEC grid, as the main power source for the Katse Dam electricity requirements.

The Semonkong hydropower project was designed for 180 kW of hydropower capacity supplemented by a 120 kW diesel generator. Currently, due to wear and tear on the Sorumsand Verksted turbine, the hydropower equipment is able to produce 125 kW only. The diesel generator has been upgraded twice since its installation and is currently a 180 kW Cummins unit. The Semonkong hydropower project, developed as part of a Norwegian development aid project, was commissioned in 1988 and officially opened in 1990. The plant powers an isolated mini-grid that serves the town of Semonkong and has 161 customers, consisting of 113 households and 48 commercial connections, all on prepaid metres. The Semonkong powerhouse was designed with provision for a second hydropower turbine. However it will only be feasible to install this second turbine if a larger reservoir is constructed for increased water supply. The hydropower project comprises an intake structure, a headrace and penstock piping, a power house and power generating equipment. The intake structure consists of a 100-metre-long concrete weir, a headrace inlet with a trash rack and a simple pipe with a light steel gate for flushing of sediment in front of the intake. The low-pressure headrace is a 290-metre-long concrete pipe and the penstock is a 150-metre-long glass fibre-polyester pipe. A standard design, cast-in-place concrete surge chamber is located at the upstream end of the penstock.[17]

There is a substantial potential for further small hydropower development in Lesotho. Technical assessments for SHP potential were conducted as part of the Power Generation Master Plan in 2009, which proposed hydropower sites with a combined capacity of nearly 88 MW. These include eight small hydropower sites with a combined capacity of 36.33 MW (Table 3).[7]

Table 3.
Hydropower sites proposed for development under the Power Generation Master Plan

Site	*Name of the river*	*Potential capacity (MW)*	*Expected annual generation (GWh)*
Polihalie HPP	Mokhotlong	19.3	83.89
Tsoelike HPP	Tsoelike	17.7	69.86
Khubelu HPP	Khubelu	14.6	64.26
Makhaleng 4 HPP	Makhaleng	9.1	58.3
Makhaleng 3 HPP	Makhaleng	8.9	39.4
Hlotse HPP	Hlotse	6.5	39.7
Phuthiatsana HPP	Phuthiatsana	5.4	18.87
Quthing 2 HPP	Quthing	2.4	9.61
Makhaleng 1 HPP	Makhaleng	2	15
Makhaleng 2 HPP	Makhaleng	1.4	6.15
Quthing 1 HPP	Quthing	0.63	2.31
	Total	**87.93**	**407.35**

Source: Department of Energy[7]

The technical potential of each proposed site was re-evaluated as part of the SREP Investment Plan for Lesotho. The analysis also covered the existing non-operational plants. The exclusion criteria for the technical analysis included urban areas, proximity to wetlands, protected areas, freshwater ecological protected areas and areas within 20 kilometres of the nearest transmission line. Four of the original 11 sites proposed in the Master Plan and the existing but non-operational small hydropower plant Tsoelike met the eligibility criteria. In addition, the analysis revealed one previously unidentified site (Table 4).[7]

Table 4.
Potential sites selected under the SREP Investment Plan for Lesotho

Name	*River*	*District*	*Type*	*Installed capacity (MW)*	*Capacity factor (%)*	*Annual generation (GWh)*
Hlotse	Hlotse	Leribe	R	6.5	70	39.7
Phuthiatsana	Phuthiatsana	Maseru	R	5.4	40	18.9
Makhaleng-3	Makhaleng	Maseru	ROR	8.9	51	39.4
Makhaleng-4	Makhaleng	Maseru	R	9.1	73	58.3
Thaba-Tseka	Malibamat'so	Thaba-Tseka	R	4.5	76	30.0
Tsoelike	Senqu	Qacha's Nek	ROR	0.40	103	3.61
Total				**34.8**		**189.91**

Source: Department of Energy[7]

Note: R – reservoir, ROR – run-of-river

In April 2015, the World Bank approved a grant for the Lesotho Highlands Development Authority (LHDA) to conduct further feasibility studies to review the economic and institutional viability of the 1,200 MW Kobong pumped-storage hydropower plant. After a public tendering process, the further feasibility studies commenced in October 2016. Results are expected in 2018.[18]

Renewable energy policy

The Lesotho Energy Policy 2015-2025 noted that renewable sources of energy and energy efficiency are expected to play a significant role in the country's future energy plans and explicitly stated the Government aim of improving access to renewable energy (RE) services and technologies. Strategies and programmes include facilitating the establishment of rural energy service companies (RESCOs) and developing an RE programme to support fossil fuel substitution.[7]

In 2015, LEWA, with the support of the African Development Bank, prepared a draft Regulatory Framework for the Development of Renewable Energy Resources, which in particular covers feed-in tariffs, procurement guidelines and templates for various licences, tenders and power purchase agreements (PPAs). As of the moment of writing of this report, the Government had not yet adopted this framework, but was looking to include many of the components thereof in the Energy Act, planned for 2018.[7] Moreover, it is expected that the UNDP/GEF project of the United Nations Development Programme (UNDP) and the Global Environment Facility (GEF) "Development of Cornerstone Public Policies and Institutional Capacities to accelerate Sustainable Energy for All (SE4All) Progress", which is to start in September 2018, will assist in a more conducive environment for renewable energy.[19,20]

Barriers to small hydropower development

In general, the conditions in Lesotho can be described as conducive for the development of small hydropower systems thanks to the availability of hydropower resources, the settlement pattern in the rural areas favouring decentralized systems and the legislation framework allowing the operation of independent power producers and distributors.[21] However, in reality it has proven to be difficult for international partners to find viable business models for the development of small hydropower in Lesotho. For example, Tarini Hydro Power Lesotho Ltd., a subsidiary of Tarini in India has been trying for a couple of years now to start two hydropower projects (the 80 MW Oxbow and 15 MW Quithing projects) but still has not been able to commence construction works.[22]

The key barriers to the development of SHP in Lesotho include:

- Lack of effective infrastructure;
- Fragmented institutional responsibilities;
- Lack of integrated planning;
- A rather small size of the potential market and the limited ability to pay on the part of the rural population;
- Limited skilled manpower required for SHP construction, operation and maintenance;
- Low general awareness of SHP as well as of other RE technologies;
- Difficulties in accessing some sites;
- Limited availability of spare parts in the local market.[11,23]

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1.4.4 Namibia

Helvi Ileka, Namibia Energy Institute; Karin Reiss, SADC Centre for Renewable Energy and Energy Efficiency (SACREEE); and International Center on Small Hydro Power (ICSHP)

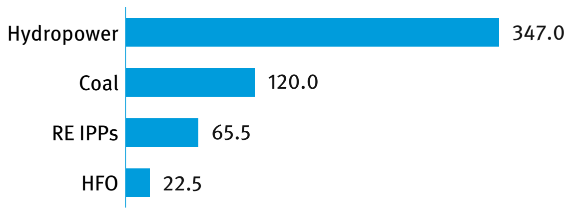
Key facts

Population	2,533,794[1]
Area	824,290 km[2]
Climate	The climate of Namibia is characterized by distinct seasons and some regional variation. In the Central Plateau area temperatures range between 30 °C in summer months and 10 °C in winter months. The coastal area is cooled by the Benguela Current. Average annual temperatures are above 22 °C in the north, between 20 °C and 22 °C in the interior and below 16 °C along the southern coast.[2]
Topography	The country's territory can be divided into three topographic zones: the Namib desert in the west, the Central Plateau and the Kalahari Desert in the east. The Namib extends along the coast and is 80 to 130 km wide. In the north, it is constricted by the Kaokoveld, the western mountain scrap of the Central Plateau. The Plateau varies in altitude from 975 to 1,980 metres above sea level. The highest mountain, Mount Brandberg at 2,573 metres, is located along the Plateau's western escarpment.[2]
Rain pattern	Precipitation is highly variable and multi-year droughts are common. Precipitation in the coastal area averages less than 50 mm per year. In the Central Plateau area humidity is normally low, with rainfall varying between 250 mm in the south and west to 610 mm in the north. Rainfall in the Kalahari Desert is similar to that of the Central Plateau.[2]
Hydrology	The only permanent rivers are the Kunene, Okavango, Mashi and Zambezi on the northern border and the Orange River on the southern border. Other rivers include the Swakop, Kuiseb, Fish and numerous smaller rivers.[2]

Electricity sector overview

As of September 2018, the maximum electricity demand in Namibia stood at 652 MW. At the same time, total installed capacity was 557 MW, of which 62 per cent was from hydropower, 22 per cent from coal, 12 per cent from renewable energy (RE) independent power producers (IPPs) and 4 per cent from heavy-fuel oil (HFO) (Figure 1).[3] The backbone of the electricity sector of Nambia is the 332 MW Ruacana hydropower plant, which was commissioned in 1975 and gained an additional 15 MW through a refurbishment completed in October 2016. The only coal-fired plant of Namibia, Van Eck, commissioned in 1972, was undergoing a rehabilitation in 2017, with three units being operated at minimum loads of approximately 11 MW. Currently, due to its aging, the plant is delivering only 30 MW of its 120 MW installed capacity. As a result, the country's total available capacity is estimated at 467 MW. Before 2016, there were two diesel-fired plants, the 22.5 MW Anixas power plant commissioned in 2011 and the 24 MW Paratus power plant commissioned in 1976, but the latter was decommissioned in 2016 after the Walivis Bay 132 kV substation was put in operation. However, it might be upgraded and brought back online with new diesel engines. Finally, there were ten solar PV power plants and one wind power plant with a combined capacity of 67.5 MW.[3,4,5]

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



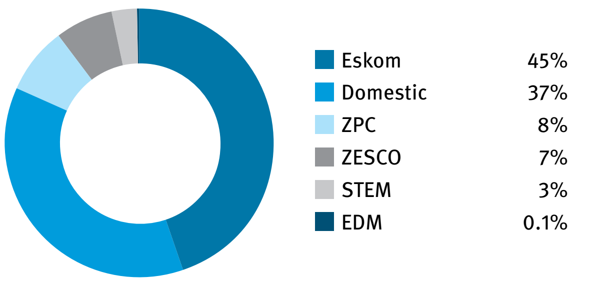
Source: MME[3]

To incentivize investments into national generation through private sector participation, the Government implemented the Renewable Energy Feed-in Tariff (REFIT) programme, which focuses mainly on solar and wind power. Between April 2015 and September 2018, 11 of the 14 projects that qualified for participation in the REFIT programme were commissioned. These projects are operated by IPPs and currently account for 15 per cent of local generation capacity supplied by the IPPs, which is to increase to 41 per cent by 2020. As of the moment of writing of the present report, a further six solar PV IPP power plants were under construction and were expected to be commissioned by December 2018, adding 72 MW of capacity. A second wind power plant of 44 MW is expected to be commissioned by 2020.[3,4,5]

Another project planned in Namibia is the 37 MW Hardap solar PV plant.[4] The Baynes hydropower project is a joint initiative of Namibia and Angola, which is planned to be developed on the Kunene River, 200 kilometres downstream of the Ruacana hydropower plant, and is to have an installed capacity of 600 MW (but only 71 MW of operational capacity during the dry season), which is to be shared equally between the two countries. The project is currently subject to a feasibility study and an environmental impact assessment.[6] Another potential site for hydropower development is the Popa Falls in the north of the country with a potential capacity of 20 MW. However, its construction has been complicated by a range of factors, including the project's potential negative impact on tourism and the environment in the area.

Even with the expansion of the country's generating capacity, the total generation still falls short of the demand.[4] The available capacity of Namibia is supplemented through imports from the Southern African Power Pool (SAPP). In particular, NamPower has agreements for 200 MW with the South African Eskom, for 50 MW with Zambia Electricity Supply Corporation (ZESCO) (however, following the drought in 2015, the capacity was reduced by 20 per cent to 39 MW) and for 80 MW with Zimbabwe Power Company (ZPC). In addition, NamPower has a non-firm supply agreement with Electricidade de Moçambique (EDM) and trades in the SAPP Day-Ahead Market.[4] In 2017, a total of 4,610 GWh was fed into the national grid of Namibia. However only 1,700 GWh (37 per cent) of this was from domestic generation by NamPower (1,660 GWh) and IPPs (40 GWh). The remainder was imported (Figure 2).[4]

Figure 2.
Domestic and imported electricity supply in Namibia in 2017 (%)



Source: NamPower[4]

Note: ZPC – Zimbabwe Power Company, STEM – Short-Term Energy Market

The vulnerability resulting from Namibia's high dependency on imported electricity has been strongly felt in the last decade. For example, in 2015 South Africa could not export peak-load electricity to Namibia on the account of its own power shortages. Moreover, a number of the agreements with the SAPP countries will expire by 2020. Due to such vulnerability of the national economy when relying on energy imports, Namibia urgently wants to increase its own generating capacity, and also to avoid buying extremely costly emergency power generation. The country's development programme for the period 2016-2020, the Harambee Prosperity Plan, foresees an increase in generation capacity to 600 MW by 2020.[7]

Besides imports, the electricity sector of Namibia is also highly dependent on generation from the Ruacana hydropower plant, which is subject to seasonal variations in the flow of the Kunene River, thus, creating certain risks for the stability of the supply.[4] Intermittent renewable energy is expected to keep playing an important role in the country's energy mix and as of the moment of writing of this report, the national utility NamPower was studying the effective models of managing the system based on renewable energy technologies, in particular, through such solutions as storage facilities.

In addition to ensuring energy independence and stability of the supply, another aim for the Government is to improve electricity access.[4] In 2016, the national electrification rate was 58 per cent.[8] While urban access to electricity was at 77 per cent, rural access was much lower, at 29 per cent.[8] Some 51 per cent of the Namibian population lives in rural areas.[9] However, with the high dispersion of the population across the country, grid extension is often unviable.

The electrification of Namibia is supported through two Government initiatives. The first of them is the Regional Electricity Distribution Master Plan (REDMP), which was first adopted in 2000 and then has been revised twice, with the latest version published in 2010. The REDMP aims to connect 1,543 out of 5,858 identified settlements to the main distribution grid over a period of 20 years. The REDMP also identified 27 potential localities for the development of mini-grids. The second initiative, the Off-Grid Energisation Master Plan (OGEMP), covers municipal areas, off-grid areas and informal settlements around urban areas. The OGEMP was developed in 2007 under the Namibian Renewable Energy Programme (NAMREP) and was financed by the United Nations Development Programme (UNDP), the Global Environment Facility (GEF) and the Namibian Ministry of Mines and Energy. The three main tools designed for the electrification of off-grid areas under the OGEMP are electrification of rural public institutions, energy shops and the Solar Revolving Fund.[10] The electrification budget of NamPower in the 2016/2017 financial year reached NAD 40 million (US$ 2.7 million). An additional NAD 22 million (US$ 1.5 million) was provided by the European Investment Bank.[4]

The Namibian power sector is dominated by NamPower, a state-owned vertically integrated electricity utility with a monopoly over generation and transmission. The utility was originally established by South Africa as a private company to operate the Ruacana hydropower project. Today, NamPower continues to maintain a strong degree of independence from the Government, despite being wholly state-owned. In the areas not served by NamPower, electricity is also distributed by local authorities and regional electricity distribution companies. In 2002, the Government launched a process of developing a single buyer model to support small power producers.[11]

The Electricity Control Board (ECB) is a regulatory authority established under Electricity Act 2 of 2000, which was later repealed by Electricity Act 4 of 2007. The ECB is mandated to exercise control over the electricity supply, including regulating electricity generation, transmission, distribution, supply, import and export through setting tariffs and issuing licences.[12] The distribution tariff for the period 2018/19 is NAD 2.22 (US$ 0.15) per kWh for small power users (up to 33 kV) and NAD 1.24 (US$ 0.08) per kWh for large power users.[13,14]

Small hydropower sector overview

There is no official definition of small hydropower (SHP) in Namibia. However for the purposes of this report a definition of up to 10 MW will be used. As of 2018 the SHP the installed capacity of Namibia was 50 kW, while the potential was estimated at 120 MW.[10,15] In comparison to the *World Small Hydropower Development Report* (*WSHPDR*) *2016*, the installed capacity decreased nine-fold, while the estimated potential increased by 11 per cent (Figure 3). Both changes are due to access to more accurate data.

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

Source: UNDP,[10] *WSHPDR 2016*,[11] MME,[15] *WSHPDR 2013*[16]

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

Presently, there is only one small hydropower plant operating in Namibia, with a capacity of 50 kW. It is located between the village of Divundu and the border with Angola, approximately 20 kilometres upstream the Popa Falls.[15] The development of hydropower in Namibia has been limited by a number of factors. First of all, due to the scarce rainfall and extensive droughts experienced by the country, water resources remain rather limited with unstable availability. Secondly, all perennial rivers available in Namibia form its borders with Angola, Zambia and South Africa, making any plans to develop hydropower subject to bilateral negotiations.[17]

A number of studies of the hydropower resources of Namibia was carried out in the 1990s. These identified a theoretical potential of approximately 9,000 GWh per year and a technically and economically feasible potential of 8,645 GWh per year. The potential of the Kunene River, which Namibia shares with Angola, was estimated at 1,600 MW. Small hydropower potential has been found mostly on the Okavango and the Orange Rivers.[17] The total potential for small-scale hydropower development in Namibia is estimated to be at least 120 MW, which could contribute approximately 0.3 TWh of electricity annually.[10]

Together with the South African Clackson Power Company, NamPower has been considering the development of the Lower Orange Hydro Electric Power Stations (LOHEPS) project in the lower Orange River catchment. The project consists of up to nine hydropower plants ranging in size from 6 MW to 12 MW, with a planned total installed capacity of 100 MW and an annual output of 650 GWh. By September 2016, the first phase of the feasibility study had been completed.[17] Furthermore, according to the 2008 National Investment Brief, there are hundreds of small farm dams that are suitable for SHP development.[11]

Renewable energy policy

The Government of Namibia aims to increase the share of renewable energy (RE) technologies in the country's energy mix, which is reflected in the National Energy Policy, the National Renewable Energy Policy, the National Integrated Resource Plan and the Harambee Prosperity Plan. IPPs have played a critical role in the development of renewable energy sources, and with NamPower's plans to develop large-scale RE projects, the role of independent companies is expected to increase.[4]

The overarching mission of the National Energy Policy of Namibia (2017) is to ensure the security of energy supplies to the country; to create cost-effective, affordable, reliable and equitable access to energy for all Namibians; to promote the efficient use of all forms of energy; to incentivize the discovery, development and productive use of the domestic energy resources (oil and natural gas, biomass, hydropower, solar, wind, uranium, coal, waste, geothermal, ocean, and wave power).[18] The National Renewable Energy Policy of Namibia (2017) aims to enable access to modern, clean, environmentally sustainable and affordable energy for the population of Namibia, fostering productive activity and development. Additionally, the Policy outlines the Government's vision for Namibia to become a leader in the development and deployment of renewable energy in southern Africa.[19]

Renewable energy procurement in Namibia is differentiated according to the size of the project:

- Net metering rules for installations £500 kW for all RE technologies;
- A Renewable Energy Feed-in Tariff (REFIT) for projects >500kW and £5 MW, including biomass, concentrated solar power, solar PV and wind power;
- A competitive auction approach for projects >5MW.[19]

In 2015, the Government gazetted the net-metering rules, which allow electricity users to install their own solar electricity generation systems to generate electricity for their own consumption to reduce their dependence on the local distributors supply.[3]

Barriers to small hydropower development

The barriers to SHP development in Namibia include:

- Scarce water resources;
- Dependency on neighbouring countries for water supply;
- Climate change is expected to exacerbate natural climate variability, creating more unpredictability of the hydrological regime;
- The legislation and policy in relation to SHP is unclear and need to be developed;
- Indigenous people are concerned about the hydropower industry and its impact on their way of life, causing a conflict over internal land use.[11,19]

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1.4.5

South Africa

Wim Jonker Klunne, Hydro4Africa; Bohuslav Barta, Energy and Water Resources Engineering Consultant

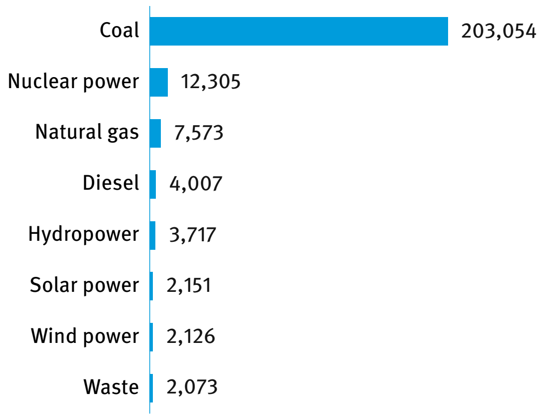
Key facts

Population	56,717,156[1]
Area	1,219,602 km[2]
Climate	South Africa is located in a subtropical region, though the Atlantic and Indian Oceans surrounding the country on three sides moderate its climate to warm temperate conditions. On the interior plateau, the high altitude (Johannesburg lies at 1,694 metres above sea level) keeps the average summer temperatures below 30°C. In the winter, night temperatures can drop to the freezing point.[2]
Topography	The territory of the country consists of a vast interior plateau rimmed by rugged hills and a narrow coastal plain. The elevation varies from about 1,500 metres above sea level in the dolerite-capped Roggeveld scarp in the south-west to 3,482 metres in the KwaZulu-Natal Drakensberg.[2]
Rain pattern	Average annual rainfall is 464 mm. Regional rainfall varies widely, from less than 50 mm in the Richtersveld (on the border with Namibia) to more than 3,000 mm in the mountains of the Western Cap. However, only 28 per cent of the country's territory receives more than 600 mm of rainfall. The Western Cape receives most of its rainfall in winter, while the rest of the country generally sees wetter summers.[2]
Hydrology	The country's largest river is the Orange River, which rises in the Drakensberg Mountains, traverses the Lesotho Highlands and joins the Caledon River between the Eastern Cape and the Free State. Other major rivers are the Vaal, Breede, Komati, Lepelle (previously Olifants), Tugela, Umzimvubu, Limpopo and Molopo.[2]

Electricity sector overview

Electricity production in South Africa is dominated by coal power. In 2016, a total of 237 TWh of electricity was generated, of which coal accounted for 86 per cent, while nuclear power provided 5 per cent, natural gas 3 per cent, diesel and hydropower almost 2 per cent each, while waste, solar and wind power accounted for less than 1 per cent each (Figure 1). Electricity imports in 2016 stood at 9,757 GWh, while exports stood at 13,540 GWh.[3]

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

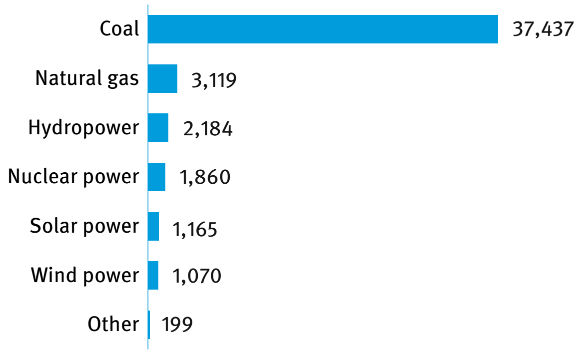


Source: Statistics South Africa[3]

In 2016, the total installed capacity of South Africa was 47,043 MW, with an almost 80 per cent share of coal-fired power plants, a 7 per cent share of natural gas-fired plants, almost 5 per cent of hydropower plants, 4 per cent of nuclear power plants, 2 per cent from solar and wind power each and 0.4 per cent from other sources (Figure 2). Approximately 91 per cent of the total installed capacity, or 42,810 MW, was owned by ESKOM and some 7 per cent, or 3,392 MW was owned by the Independent Power Producers (IPP). The remaining 2 per cent of capacity was owned by municipalities (Table 1).[4]

The institutional framework of the electricity sector in South Africa includes the Department of Energy (DoE) and the National Energy Regulator of South Africa (NERSA). The DoE is responsible for establishing the policy, legal and regulatory framework for the energy sector. Its goal is to ensure the development, utilization and management of the energy resources in the country, aiming for the provision of secure, sustainable and affordable energy.[5] NERSA is mandated to regulate the electricity, piped gas and petroleum industries, it issues licences, sets and approves tariffs and charges, mediates disputes and ensures fair competition.[6] The South African National Energy Development Institute (SANEDI), carries out research and development activities to promote green energy technologies and energy efficiency.[7]

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



Source: RECP[4]

The electricity prices in South Africa depend on the supplier (ESKOM or municipality) as well as the quantity of electricity used, the period (time or season) when the electricity is used, the volume of the supply, the geographic location of the customer, the voltage at which electricity is supplied and the cost of connecting to the supply. For the period 2018/2019, prices of electricity per kWh provided by ESKOM to residential consumers in urban areas ranged from ZAR 0.4978 (US$ 0.033) to ZAR 3.5503 (US$ 0.230) (VAT included).[8]

Table 1.
Nominal electricity generating capacity in South Africa (MW)

	Coal	*Gas*	*Nuclear*	*Wind*	*Solar*	*Hydropower**	*Other*	*Total*
ESKOM	36,441	2,409	1,860	100	–	2,000	–	42,810
Municipalities	536	122	–	–	–	174	–	832
IPPs	460	588	–	970	1,165	10	199	3,392
Total	**37,437**	**3,119**	**1,860**	**1,070**	**1,165**	**2,184**	**199**	**47,034**

Source: RECP[4]

Note: *Including pumped-storage hydropower plants

The commitment of South Africa towards emissions reduction, as indicated in the Intended Nationally Determined Contribution (INDC) to the United Nations Framework Convention on Climate Change (UNFCCC), has triggered the development of a Government-backed renewable energy procurement programme. In 2010, the Department of Energy presented the Integrated Resource Plan (IRP2010), outlining the electricity generation mix for the period up to 2030. According to the policy-adjusted development plan that was approved by the Cabinet, the country will see 17.8 GW of renewable energy as part of its energy mix in 2030. The main source of hydropower in the IRP2010 will come from imported electricity (approx. 2.6 GW by 2030), while local, small-scale hydropower shares with landfill gas-based electricity an allocation of 125 MW.[9] Although an updated IRP was produced in 2013, based on the new data on the costs of the different technologies modelled, the IRP2010 is the only Cabinet-approved version. During 2017 and 2018 an update of the IRP was developed, which is expected to be tabled to the Parliament in the second half of 2018.

The energy mix scenario of the IRP is implemented through the Renewable Energy Independent Power Producers Procurement Programme (REIPPPP). The first three bidding windows of this programme were procured by 2015, after which the signing of the Power Purchase Agreements for the windows 3.5 and 4 was stalled until early 2018, causing a decrease in the (international) interest in the renewable energy sector of the country. However, the signing of the outstanding PPAs in April 2018 brought new hope, with developers cautiously preparing for bidding window 5, which is expected to open in November 2018.

The REIPPPP process has initiated substantial activity in the hydropower sector. In total just over 19 MW of installed hydropower capacity has been procured from three hydropower plants (Table 2).[10]

Table 2.
Hydropower capacity procured under the REIPPPP

Bidding window	*Hydropower plants*	*Capacity (MW)*
1	None	-
2	Stortemelk Power Plant Neusberg Hydro Electrical Project	4.40 10.00
3	None	-
3.5	None (this window was solar CSP only)	-
4	Kruisvallei Hydro	4.70
	Total	**19.10**

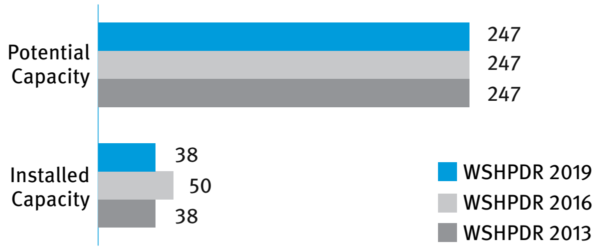
Source: Smit[10]

Small hydropower sector overview

During the first three bidding windows of the REIPPPP process the maximum size of small hydropower plants was set at 10 MW. However, in the Request for Qualifications and Proposal for the third bidding window in June 2014, a new capacity limit of 40 MW was introduced for small hydropower.[11] However, the draft Policy on Sustainable Hydropower Generation by the Department of Water and Sanitation (DWS) still uses an upper limit of 10 MW.[12] As the DWS policy is not yet officially approved, the 40 MW as outlined in the REIPPPP process will be assumed as the official definition. However, for the purpose of comparison with previous reports, this report will use data on hydropower up to 10 MW.

In 2016, the installed capacity of small hydropower up to 10 MW in South Africa stood at 38 MW, while potential is estimated at 247 MW.[13,14] Compared to the results of *the World Small Hydropower Development Report (WSHPDR) 2016*, potential capacity remained unchanged, while installed capacity decreased by 24 per cent, returning back to the level reported in the *WSHPDR 2013*. The decrease is due to access to more accurate data (Figure 3).

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



Source: IRENA,[13] Barta,[14] *WSHPDR 2016*,[15] *WSHPDR 2013*[16]

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

Although not documented to a great detail, small-scale hydropower used to play an important role in the provision of electricity to urban and rural areas of South Africa, particularly in the municipalities situated along the foothills of the Drakensberg mountain range. The first provision of electricity to the cities of Cape Town and Pretoria was based on the small-scale hydropower, while also smaller towns started local distribution of electricity through isolated grids powered by small hydropower plants. However, with the expansion of the national electricity grid and the cheap, coal-generated power supplied through the grid, large numbers of these systems were decommissioned. A typical example is the Sabie Gorge hydropower plant with three 450 kW turbines, which was commissioned in 1928 to serve the town of Sabie in Mpumalanga and closed in 1964 after the area had been connected to the national ESKOM grid.[17] Between 1917 and the mid-1950s, some 150 pico- to mini-hydropower plants were installed in South Africa. A few of the survived plants are being refurbished now.

After approximately 30 years of neglecting the hydropower potential of the country, the first new small hydropower plant was commissioned in 2009 in the Sol Plaatje Municipality in the Free State province and approximately 20 stations are currently in different stages of development.[18,19]

The South African Renewable Energy Database, as developed by the CSIR, ESKOM and the former Department of Minerals and Energy (divided into the Department of Minerals and the Department of Energy in 2009), investigated the available renewable energy resources in the country, including the potential for hydropower.[20] As a follow-up the resources available for the Eastern Cape region were detailed as a part of the three-year investigative project entitled "Renewable energy sources for rural electrification in South Africa". The primary objective of the latter project was to identify the commercially viable opportunities for rural electrification in the Eastern Cape Province of South Africa using wind power, hydropower and biomass.[21]

The "Baseline study on Hydropower in South Africa", which was developed as part of the Danish support to the South African Department of Minerals and Energy, investigated the installed capacities of hydropower in South Africa and the potential for new developments. The study concluded that twice as much as the current installed hydropower capacity below 10 MW can be developed in the rural areas of the Eastern Cape, Free State, KwaZulu Natal and Mpumalanga.[22] A later publication of 2011 gave new insights into the potential of small hydropower in South Africa by including the hydropower potential of water transfer systems and gravity fed water system, mentioning a total potential of 247 MW, of which 15 per cent has been developed so far.[14]

The small hydropower plants in South Africa can be divided into the following groups: 1) grid-connected plants commissioned prior to the REIPPPP process; 2) plants installed under the REIPPPP process; 3) grid-connected systems that fall outside the REIPPPP process; and 4) stand-alone systems not feeding into the national grid.

The grid-connected small hydropower plants introduced prior to REIPPPP include the First and Second Falls**,** Ncora**,** Lydenburg**,** Friedenheim and Bethlehem hydropower plants**.** Financed by the former Transkei Government, four hydropower plants were built between 1980 and 1984 in the Eastern Cape on the Mbashe and the Tsomo Rivers and later handed over to ESKOM – Colley Wobbles, First Falls, Second Falls and Ncora. The First Falls plant has two 3 MW units with the provision for a future third machine and the Ncora plant has a single 1.6 MW unit.[23] The Lydenburg plant commissioned in 1982 has one Gilkes Pelton turbine of 2.6 MW. The system is operated by MBB of Nelspruit under a contract with the local municipality.[19] The Friedenheim plant consists of two Sulzer Francis turbines of 1 MW each. It is owned by the members of Friedenheim Irrigation Board and operated on their behalf by engineering firm MBB. It has been running since 1987 and sells the bulk of the generated electricity through a Power Purchase Agreement (PPA) to the local Mbombela Municipality.[19] Bethlehem Hydro Pty Ltd owns two small hydropower plants that are normally referred to as "Bethlehem hydro" – the 3 MW Sol Plaatje power plant near the town of Bethlehem, which was commissioned in November 2009, and the 4 MW Merino power plant close to the town of Clarens. These two plants were the first addition of hydropower generation capacity in the last three decades.[19] Both the Sol Plaatje and the Merino installations are dependent on the flow regime of the Lesotho Highlands Water Project (LHWP), the water transfer project supplementing the Vaal Dam storage in the Gauteng province with water from Lesotho.

The hydropower plants installed and foreseen under the REIPPPP process are Neusberg and Stortemelk in the second round and Kruisvallei in the fourth round. The Neusberg plant of Kakamas Hydro Electric Power is the first run-of-river small hydropower scheme to be delivered under the REIPPPP programme and is located on the Orange River near Kakamas in the Northern Cape province. Although the plant has three 4.01 MW Kaplan turbines, it delivers 10 MW of baseload power to the national grid in order to qualify under the old requirements of the REIPPPP.[24,25] The construction of the plant began in June 2013 and operation began in

January 2015, on time and on budget. It was officially opened on March 3, 2015.[26] The Stortemelk hydropower plant (4.4 MW) was developed as a greenfield project by REH Project Development (formerly NuPlanet Project Development). The plant, commissioned in 2016, has an installed capacity of 4.5 MW and has won several rewards, including for its architecture.[27] The Kruisvallei project selected in the fourth round of the REIPPPP programme has a capacity of 4.7 MW and is planned to be located on the Kruisvallei dam in the Ash River (the same as the Merino and Stortemelk installations). As of September 2018, the construction of the plant had not started.

The future of grid-connected systems is closely linked to the Government's policy on renewable energy development. The allocation in the IRP2010 and the REIPPPP of 195 MW (up from the original 75 MW) of small hydropower capacity is less than the estimated potential and might therefore limit small hydropower development. The future for small hydropower in South Africa will see two main parallel tracks – grid-connected projects that will feed into the national electricity system, and small-scale systems for private use (not feeding into the grid, irrespective of whether a grid connection is available or not). These tracks can be supplemented by a third category of isolated systems for rural electrification purposes. Several project developers have indicated an intention to submit hydropower projects for the upcoming fifth bidding window. These include some larger plants along the Orange River and in the Eastern Cape Province. The small-scale systems are expected to grow based on the foreseen raise in electricity prices and increased reliability of the grid. The development of small hydropower potential can be opened if the Government fully recognises and adheres to the Public Private Partnership (PPP) implementation process in developing the renewable energy resources.[12]

A number of grid-connected systems are in operation at the moment in South Africa that either deliver power to the national utility or use the national grid to wheel power to its customers. Examples of these are Murludi (44 kW), Harlestone (325 kW), Howick Falls (500 kW) and L'Ormarins (2 MW + 325 kW).[19]

A substantial number of micro-hydropower plants are in place in the KwaZulu Natal and Eastern Cape region, providing power to individual farms. There are also in-flow turbines installed in water transfer systems as well as at underground operations of mines (with a total installed capacity of approximately 80 MW). Thus, the City of Cape Town operates hydropower turbines at four of its water treatment plants (the 700 kW Blackheath, 1.475 MW Faure, 340 kW Steenbras and 260 kW Wemmershoek plants), while eThekwini is developing six mini-hydropower sites of some 1,050 kW of total capacity along the Northern Aqueduct and another 5.5 MW at the Break Pressure Tanks of the Western Aqueduct. Rand Water has some 15 MW of small-scale hydropower at its four pressure break stations. The City of Johannesburg released a tender for 3 MW of installed capacity, while also Buffalo City is having a significant hydropower potential, as assessed in 2013, at its water supply and sanitation infrastructure.[28]

A 15 kW pilot plant was installed at the Pierre van Ryneveld reservoir in Pretoria as part of a University of Pretoria research project, while Bloemwater, the water distribution company of the city of Bloemfontein, commissioned a 96 kW system at the inlet of a water reservoir that is now providing power to the company's headquarters.[29] Another most recent project is the Kwa Madiba (50 kW) community plant on the Thina River in the Eastern Cape Province.

As of 2018, ESKOM was operating three large hydropower plants (Gariep of 360 MW, Vanderkloof of 240 MW and Colley Wobbles of 42 MW) and three small plants: First and Second Falls (6 MW + 11 MW) and Ncora (1.6 MW). The energy storage in South Africa is capacitated by four large pumped-storage schemes, namely the Steenbras PSS (180 MW), Drakensberg PSS (1,000 MW), Palmiet PSS (400 MW) and Ingula PSS (1,330 MW).[30]

Besides the operational systems, South Africa has a number of existing, inactive small-scale installations that could be refurbished, such as Belvedere (2.1 MW), Ceres (1 MW), Hartbeespoort (potential up to 8 MW), Teebus (up to 7 MW) and others.[14]

Renewable energy policy

South Africa has a full suite of policies in place to support the energy sector: White Paper on the Energy Policy of the Republic of South Africa (December 1998); the National Energy Act (Act No. 34 of 2008); the Electricity Regulation Act (Act No. 4 of 2006); White Paper on Renewable Energy (2003); and Renewable Energy IPP Procurement Programme 2015.[7] For the implementation of RE technologies, the REIPPPP is the main vehicle. The REIPPPP was launched by the Department of Energy in 2011, switching from the feed-in tariff system that had been created in 2009.

The small hydropower sector in South Africa has recently received support from a number of initiatives. The Water Research Commission of South Africa has been supporting the University of Pretoria in implementing in-flow hydropower in water transfer and distribution systems.[31,32] Under the SAled programme by USAID, the !Kheis Local Municipality and the eThekwini Metropolitan Municipality have been supported in developing their hydropower resources.[33,34] The EEP Africa programme has supported a private sector developer in the execution of a feasibility study for the Tina Falls hydropower station in the Eastern Cape. While the original target was 8 MW, this study has indicated a potential of 22 MW. The Environmental Authorization has been awarded to the private developers and this greenfield project will likely see an implementation stage.[35]

Barriers to small hydropower development

The constraints hampering more extensive development of small hydropower in South Africa include:

- A lengthy and expensive process for a successful Environment Impact Assessment (EIA);
- Occasional difficulties in obtaining the Water Use Permit as per National Water Act (No. 36 of 1998) is sometimes difficult to obtain;
- Difficulties obtaining an acceptable Power Purchase Agreement (PPA);
- Land issues with regard to access to and permission of crossing private or state land;
- Prior possession of all other permits is a prerequisite for obtaining the National Energy Regulator licence;
- Local banks are not in favour of financing small hydropower projects.

With regard to the above constraints, developers interested in installing small hydropower plants tend to focus on the development of projects situated along the existing water distribution networks (mainly at the local Government level as the water use environmental permits are already in place) according to the Public Private Partnership principles. All in all, it is expected that small hydropower can play a small but important role in the future energy mix of the country.

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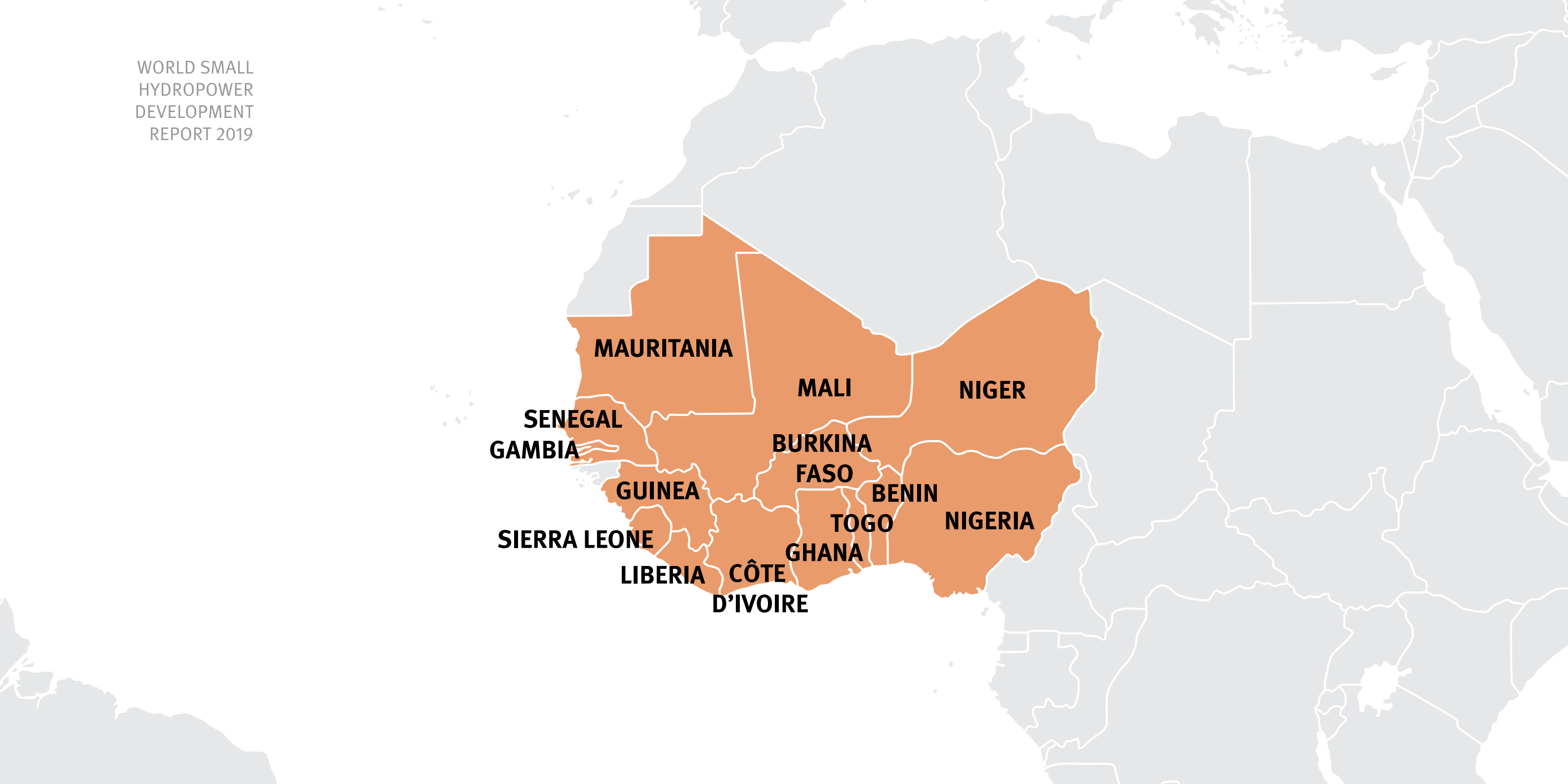

1.5 Western Africa

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Introduction to the region

Western Africa comprises 16 countries, of which 15 are members of the Economic Community of West African States (ECOWAS) and one, Saint Helena, is a self-governing territory. The region is bordered by the Sahara to the north and the Atlantic Ocean to the west and south. This report focuses on 14 countries, namely Benin, Burkina Faso, Côte d'Ivoire, Gambia, Ghana, Guinea, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone and Togo. All countries listed, with the exception of Mauritania, are members of ECOWAS. An overview of the countries in Western Africa is presented in Table 1.

The climate in the region can be grouped into six different zones from north to south – desert, semi-arid desert, semi-arid tropical, pure tropical, transitional tropical and transitional equatorial. Precipitation ranges from almost zero in the north of Mali and Niger to more than 3,000 mm in some coastal areas in Liberia. Generally, the seasonality (the difference between dry and wet seasons) is very high within the region.

There are significantly high mountains and appropriate topographic conditions for small-scale hydropower development, especially in Guinea, Sierra Leone, Liberia and Nigeria, as well as in Côte d'Ivoire, Benin, south-west Burkina Faso, Ghana, southern Mali and Togo. Mount Bintumani (also known as Loma Mansa) located in Sierra Leone is the highest peak in continental Western Africa, at 1,945 metres.

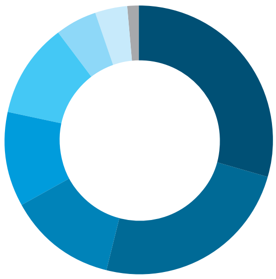
Several rivers of regional importance originate from the Guinean highlands, including the Senegal, Gambia and Niger rivers. Other important basins include the Volta basin and the Benue basin (which discharges into the Niger River). All Western African rivers discharge into the Atlantic Ocean, with the exception of the Yobe River which flows towards Lake Chad. A unique topographical feature is the Inner Delta of the Niger River, which during the flood season forms one of the largest wetlands in the world.

In large parts of Western Africa, runoff is only a small fraction of rainfall, as most of the rainfall is lost via evapotranspiration. The regional distribution of runoff correlates with the rainfall distribution. Regions with annual rainfall below 800 mm produce very little runoff. In contrast, runoff is quite considerable in regions with high rainfall.

In most parts of Western Africa, the discharge regime shows a strong seasonality with high flows from August to October and low flows from December to May. This seasonality in discharge is driven by the rainfall regime (the rainy and dry seasons). In some coastal regions, there is a second discharge peak in June.

The greatest share of the small hydropower (SHP) installed capacity up to 10 MW, which is estimated at 44 MW, is located in Sierra Leone and corresponds to 30 per cent of the total (Figure 1). However, this total value of the region's installed SHP capacity up to 10 MW does not include the installed capacity of Nigeria, for which data up to 10 MW are not available.

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



Source: *WSHPDR 2019*[3]

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

Table 1.
Overview of countries in Western Africa

Country	*Total population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Benin	11.2	53	41	262	323	0.6	N/A
Burkina Faso	19.2	71	20	315	973	34	139
Côte d'Ivoire	24.3	50	64	2,199	9,948	879	2,047
Gambia	2.1	39	48	99	435	0	0
Ghana	29.3	45	83	3,795	13,022	1,580	5,561
Guinea	12.7	64	34	602	503	367	428
Liberia	4.7	49	20	131	113	93	0
Mali	18.5	58	35	672	1,905	316	1,102
Mauritania	4.4	47	42	306	900	0	229*
Niger	21.5	84	56	173	499	0	0
Nigeria	193.4	50	45	13,392	29,000	2,002	N/A
Senegal	15.9	53	65	950	3,920	0	332*
Sierra Leone	7.6	58	20	163	330	56	N/A
Togo	7.8	59	47	230	1,100	67	N/A
Total	**372.6**	-	-	**23,289**	**62,971**	**5,348**	**9,838**

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

Note: *Hydropower generation from the country's share in the plants located in Mali and operated on a shared basis.

Small hydropower definition

The definition of SHP varies throughout the region. Many countries use the ECOWAS classification of hydropower, according to which SHP is defined as hydropower plants with capacity up to 30 MW, medium hydropower between 30 MW and 100 MW and large hydropower above 100 MW.[6] Ghana has the lowest upper limit for SHP at 1 MW. For the countries that do not have an official definition of SHP, the current report uses the ICSHP definition of up to 10 MW.

Regional small hydropower overview and renewable energy policy

The installed capacity of SHP up to 10 MW in Western Africa is 44 MW (Table 2), which accounts for 0.8 per cent of the total installed hydropower capacity of the region and 7 per cent of the estimated potential up to 10 MW. However, this estimate does not include the capacity of Nigeria, for which data up to 10 MW are not available. Compared to the *WSHPDR 2016*, the region's installed capacity up to 10 MW (for Nigeria data up to 30 MW are used) increased by 25 per cent (Figure 3). According to the ECOWAS data, in 2017 the installed capacity of SHP up to 30 MW of nine countries in the region (Benin, Burkina Faso, Côte d'Ivoire, Guinea, Liberia, Mali, Nigeria, Sierra Leone and Togo) stood at approximately 194 MW.[7] The region's SHP potential according to local definitions is estimated to exceed 2,000 MW, of which to date almost 5 per cent has been developed (Figure 2).

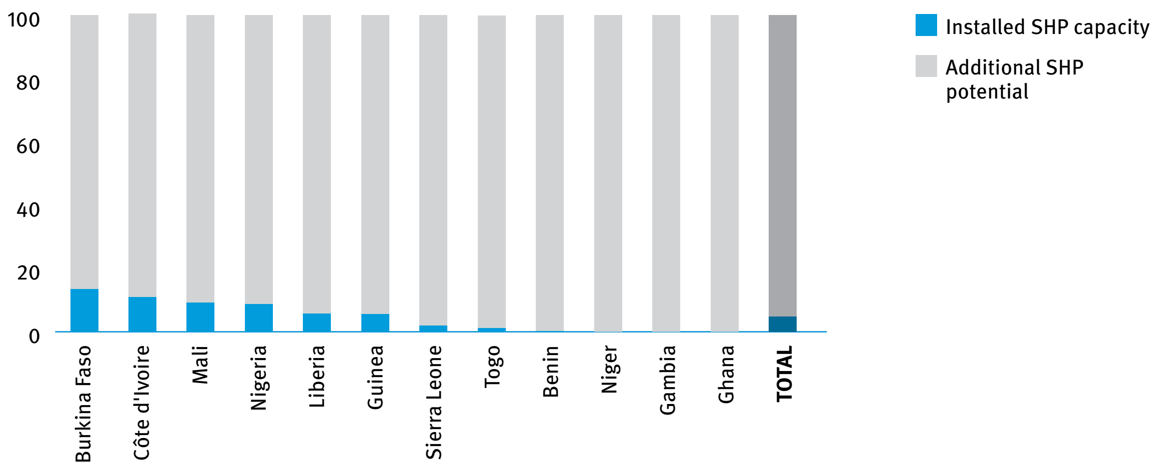
Table 2.
Small hydropower capacities in Western Africa (local and ICSHP definition) (MW)

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed (<10 MW)*	*Potential (<10 MW)*
Benin	up to 30	0.6	304.9	0.6	69.9
Burkina Faso	-	-	-	2.3	17.0
Côte d'Ivoire	up to 10	5.0	45.7	5.0	45.7
Gambia	up to 30	0	N/A	0	12.0
Ghana	up to 1	0	12.1	0	17.4
Guinea	-	-	-	10.8	198.0
Liberia	up to 30	4.9	85.9	4.9	56.4
Mali	up to 30	5.7	61.7	5.7	28.4
Mauritania	-	-	-	0	N/A
Niger	-	-	-	0	8.0
Nigeria	up to 30	64.2	735.0	N/A	N/A
Senegal	up to 10	0	N/A	0	N/A
Sierra Leone	up to 30	12.9	639.0	12.9	12.9*
Togo	-	-	-	1.6	144.0
Total		-	-	**44**	**610**

Source: *WSHPDR 2019*,[3] ECREEE,[8] ECREE[9,10]

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

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



Source: *WSHPDR 2019*[3]

Note: This Figure illustrates data for local SHP definitions or the definition up to 10 MW in case of the absence of an official local one. For Gambia the data is presented for the SHP definition up to 10 MW due to the absence of data on potential capacity according to the local definition. Mauritania and Senegal are not included due to 0 MW of installed capacity and the lack of data on potential capacity.

Most rural communities in Western Africa still lack access to electricity. Meanwhile, the ECOWAS white paper stipulates that up to 20 per cent of new generation additions in rural and semi-urban areas should come from renewable energy (RE) sources. Additionally, the ECOWAS Renewable Energy Policy set the goal to increase the share of decentralized rural renewable electricity services (e.g. mini-grids and standalone systems) to 22 per cent by 2020 and 25 per cent by 2030. The majority of ECOWAS member states still experience difficulties in implementing these requirements.

Grid extensions, isolated mini-grids and standalone systems are adequate solutions to provide electricity access with socio-economic developmental objectives, including community and productive uses. Isolated mini-grid solutions are required in many Western African countries that have limited national grid access in the rural areas as stepping stones to grid-based access. In some cases, micro-grids are long-term solutions. Worldwide, the International Energy Agency (IEA)'s World Energy Outlook has projected that approximately 60 per cent of households not connected to the grid at present would obtain electricity through such systems.[11] It is suggested that 128,000 mini-grids will be needed in the ECOWAS region to achieve the regional targets.

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

With regards to hydropower, **Benin** has great potential, in particular in SHP up to 30 MW and large-scale hydropower, but also mini- and micro-units. While the country's current SHP installed capacity (for SHP up to 30 MW) is 0.6 MW, three other sites up to 30 MW are in the planning stages and another 96 sites have been identified as potential for SHP development. Compared to the *WSHPDR 2016*, the installed SHP capacity increased by 100 kW, which is due to access to more accurate data.

In **Burkina Faso**, although SHP installed capacity has remained unchanged since the *WSHPDR 2013*, SHP is slated for an increase in installed capacity. The Samandeni dam has been already built, and the construction of a 2.5 MW plant on it is reported to be underway. The currently available SHP plants (up to 10 MW) – the Tourni (0.6 MW) and the Niofila (1.68 MW) – provide 2.3 MW of capacity. The country also plans the extension of the Bagré dam and the improvement of its economic profitability. A number of other projects have been considered for development, however, no progress has been made in this regard as of yet.

In **Côte d'Ivoire**, there is a single operational SHP plant of 5 MW, which was constructed in 1983. However, the plant is currently in need of refurbishment. When drawing upon the ECOWAS definition of up to 30 MW, the country's SHP capacity increases to 55 MW due to the Ayame 1 and Ayame 2 plants. Studies conducted in previous years have identified promising hydropower development projects, with a total potential of 40.7 MW (for SHP up to 10 MW).

Gambia has no installed hydropower capacity. However, within the framework of the OMVG (Gambia River Basin Development Organization), hydropower projects are planned in neighbouring countries with benefits for Gambia. Cross-border trade will be important to get out of the country's current situation of isolation in regards to the energy supply. There are five hydropower projects being planned or considered in conjunction with the OMVG that will affect Gambia, and are forecasted to have a combined capacity of 68 MW.

In **Ghana**, the Sustainable Energy for All Action Plan 2012 set targets of having 10 per cent of the energy mix from RE and of reducing the share of combustible RE sources to below 50 per cent by 2020. Currently, there are no SHP plants and there are no financial mechanisms specifically for SHP. However, there are a number of incentives for rural electrification as part of the National Electrification Scheme.

The Government of **Guinea** has several plans for the development of SHP plants in its pursuit of increasing efficiency of and access to the grid. Four projects with a combined capacity of 13.7 MW have been prioritized. The Government has already developed hydropower plants in Tinkisso (1.65 MW) in order to generate electricity for the cities of Dabola, Faranah and Dinguiraye, and at Kinkon (3.5 MW) in order to generate electricity for the cities of Pita, Labe and Dalaba. The total installed capacity of SHP up to 10 MW in Guinea is 10.8 MW, while the potential is estimated at 198 MW. Compared to the *WSHPDR 2016*, the SHP installed capacity slightly decreased due to the Seredou plant not being in operation anymore.

The current installed SHP capacity (up to 30 MW) in **Liberia** comes from two plants: a community-owned 60 kW plant and a concession-owned 4.8 MW plant of the Firestone company. The increase of 0.8 MW compared to the *WSHPDR 2016* is due to access to more accurate data. A number of SHP projects are currently being implemented and/or have been earmarked. The construction of a 1 MW Mein River plant was expected to be completed in 2015, but has been presently stalled. Additionally, a feasibility study has been completed for a 15 kW project along the Wayavah Falls and a number of hybrid renewable energy systems have been developed under the Scaling Up Renewable Energy Programme (SREP).

The installed capacity of SHP in **Mali** remained unchanged since the *WSHPDR 2016*, at 5.7 MW (for SHP up to 30 MW). However, a number of micro- and mini-hydropower plants are under development with the support of SREP and the African Development Bank. These projects combined are to bring an additional capacity of 30.5 MW. It is estimated that there is at least 56 MW of SHP potential up to 30 MW that could be developed in the country.

Mauritania has some hydropower capacity, however, all of it originates from large-scale plants developed through the Senegal River Basin Development Organization (OMVS) and, hence, is shared among the participating countries. The country has no SHP plants, and the SHP potential remains unknown.

Similarly, **Niger** has no installed SHP capacity, however, four rivers on its territory have been identified to have a combined potential for SHP development of 8 MW (for SHP up to 10 MW).

Conversely, **Nigeria** has the highest SHP installed capacity in the region at 64.2 MW and an economic potential of at least 735 MW (both for SHP up to 30 MW). A number of projects in the country were developed with the support of the UNIDO and a significant number of potential sites have been identified. Compared to the *WSHPDR 2016*, the installed capacity increased by 9.2 MW. However, the progress in SHP development has been slower than expected. It is planned to encourage the investment of the private sector into small, mini- and micro-hydropower projects, in particular in rural and off-grid areas.

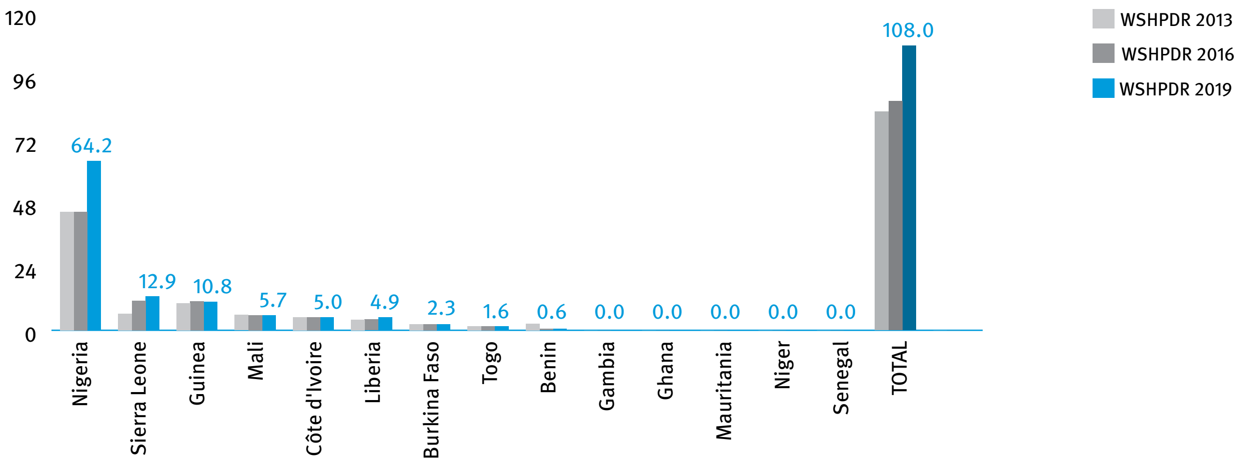
While **Senegal** does not currently have any installed hydropower plants on its territory, hydropower in general plays an important role in electricity generation for the country. Under the OMVS framework, the Manantali plant in Mali provides Senegal, Mali and Mauritania with 200 MW of electricity. Senegal also receives electricity from the 60 MW Felou plant shared with Mali and Mauritania.

In **Sierra Leone** the total SHP installed capacity is 12.9 MW (following the 30 MW definition). Between 2015 and 2017 three new SHP plants were commissioned – the 2.2 MW project in Charlotte, 2 MW project in Port Loko and 3 kW project of Makali. Compared to the *WSHPDR 2016*, installed capacity increased by approximately 0.7 MW, which is due to both new developments and access to more accurate data. A Small Hydropower Technology Centre was also opened at Fourah Bay College in 2016.

Even though **Togo** has only one SHP (up to 10 MW) plant of 1.6 MW currently in operation, the Government is investing to change this in the foreseeable future. Seven economically feasible sites with a combined capacity of 40 MW have been identified. Since the *WSHPDR 2016*, installed SHP capacity has remained unchanged.

Feed-in tariffs (FITs) are in place in Ghana and Nigeria, while the legislation of Gambia and Senegal has laid the foundation for the introduction of a FIT scheme. In Sierra Leone, the Government plans to introduce policies for FITs.

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



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

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

Barriers to small hydropower development

While there is significant potential for SHP development in West African countries, the widespread implementation of SHP is hampered by a number of factors. The most common barriers for the region are the lack of reliable hydrological data, the limited regulatory frameworks and the lack of financial incentives, which make the SHP sector unattractive for private investors. Another critical barrier is the lack of local technical expertise and equipment. Climate change has affected a number of countries in the region, complicating the development of hydropower projects. Public awareness of the potential and benefits of SHP remains rather low in the region.

Moreover, the rivers of **Benin** are prone to a low flow and drying and in **Burkina Faso** droughts create significant water access problems. In **Burkina Faso** and **Côte d'Ivoire**, the Governments have prioritized other types of renewable energy, while overlooking SHP. In **Gambia**, the cost of electricity generation is very high, and also tariff and power purchase agreement negotiations for generation and distribution licences can sometimes take years. In **Ghana** and **Nigeria**, investment costs remain very high. **Guinea** requires the development of the grid network to connect remote areas as well as the improvement of the management system of the national utility. Grid availability in rural areas is a problem for **Liberia** as well, but also changes in land use patterns may lead to changes in stream flow patterns in the country.

In **Mali**, the sector remains unattractive due to the lack of tax-free zones and guarantees for investors during site acquisitions, the uncompetitive business environment, limited coordination among relevant institutions, limited financial resources among the country's population, difficult return of investment and the perception of the country's energy sector by international investors as risky. **Mauritania** also lacks a local capacity to develop and operate SHP projects. In **Niger**, the most important barrier is the limited SHP potential. For **Senegal**, other significant factors hindering SHP development are the inadequate tax base and collection as well as the need to facilitate the integration of electricity from renewable energy sources into the grid. **Sierra Leone** suffered from 11 years of war that caused economic damage and widespread destruction of infrastructure. **Togo** has also experienced dilapidation of transportation and distribution lines.

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1.5.1

Benin

Bill Clement, Ministry of Energy, Water and Mining; and International Center on Small Hydro Power (ICSHP)*

Key facts

Population	11,175,692[1]
Area	114,763 km[2]
Climate	The climate in Benin varies from transitional equatorial in the south to tropical and increasingly dry in the north.[2] Average maximum temperatures across the country vary between 28.0 °C and 33.5 °C (April to March), while the average minimum fluctuates between 24.5 °C and 27.5 °C (July to September).[3]
Topography	The country is fairly flat, with five natural regions. The first of these is a coastal strip, which is low and sandy and limited by lagoons. The next is a central, hilly plain that rises gradually to 200-400 metres from south to north around Nikki, subsequently dropping to the Niger Valley and Kandi Basin. The third region is the Kandi Basin in the north-east, which is a plain drained by the Sota River and its tributaries, which flow in various flared valleys. The fourth region is the mountain chain Atacora in the north-west, where the highest point of the country is located, Mount Sokbaro (658 metres). Lastly, there are the vast plains of Gourma in the extreme north-west, between Atacora and the border with Burkina Faso and Togo. Moist savannahs occupy most of the country.[4]
Rain pattern	Two rainy seasons follow one another during the year, one between March and July and the other between September and November. Levels of recorded rainfall range from 850 to 1,300 mm, with the maximum in Donga and Ouémé.[3] Gradually, moving north, the Sahelian climate becomes more dominant, with a long dry season from October to April and one rainy season from May to September. Therefore, in the north, rainfall is lower (890 mm, except on the massif of Atakora, which receives 1,300 mm in Natitingou). In the south, the average annual rainfall decreases from Porto-Novo (1,200 mm) to Grand-Popo (820 mm).[2]
Hydrology	The hydrology is divided into four major basins. In the north, the Niger Basin collects the water following tributaries from west to east. These include the Mekrou (410 km), Alibori (338 km) and Sota (250 km). In the north-west, there is the Volta Basin, which captures the Pendjari, which in turn captures the Kounné rivers. The Kounné rivers include the Tigou, Sarga Podiega, Magou and Yabêti. In the south-east, the Ouémé Basin captures the Zou, Okpara and other rivers. In the south-west, the Mono Basin and Sazué lead to a lagoon system at the bottom of the basin. This is because the Sazué has two tributaries, the Dévédo (22 km) and Savédo (40 km).[4]

Electricity sector overview

In Benin, the energy sector is highly dependent on biomass (firewood and coal) and relies on imports for its fuel and electricity needs. In 2015, biomass accounted for 50.6 per cent of final energy consumption and fossil fuels for 46.7 per cent, while electricity for the remaining 2.7 per cent.[5] The amount of biomass used for energy purposes in Benin has caused a significant extent of forest degradation. While the country has vast renewable energy (RE) resources, they remain significantly undeveloped. The regulating authority for the energy sector is the General Directorate of Energy, while the Electricity Regulatory Auhtority (ARE) is in charge of the electricity sector.[1]

The total installed electricity capacity is 261.6 MW, which is predominantly from thermal power (Figure 1). An additional 65 MW comes from the shared Nangbeto hydropower plant on the Mono River in Togo.[6] The Nangbeto hydropower plant is jointly owned both by Benin and Togo. According to the Benin-Togo Electricity Code, the two countries benefit from shared resources and utility management under the bi-national Communauté Électrique du Benin (CEB), which is primarily in charge of the production and importation of electricity for both nations.[7,8,9] In addition, the Benin-Togo electricity agreement allows for the capacity available from the CEB to be split between the two nations, with 53 per cent going to Benin and 47 per cent to Togo.[10] Benin also has a small hydropower (SHP) plant, Yeripao SHP, with a capacity of 0.6 MW, on its territory.[6] However, the plant is currently offline. Although the capacity from the Nangbeto hydropower plant is usually taken into account in the country's energy balance, since it is located outside of the country's territory, in this report the total installed hydropower capacity for Benin is considered to be only 0.6 MW.

* *WSHPDR 2016* updated by ICSHP

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

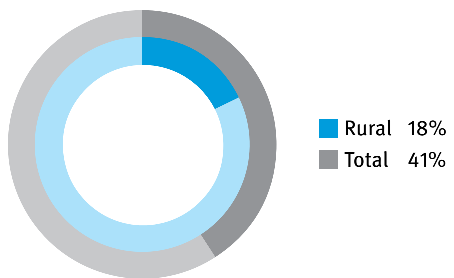
Source: Millenium Challenge Corporation[6]

The CEB receives its supply of electricity from the Nangbeto Dam in Togo (65 MW), the Cotonou Gas Turbine (20 MW) and the Lome Gas Turbine (20 MW).[11] The import supply is from the Volta River Authority (VRA) in Ghana (10-90 MW), Sunon Asogli Power Limited in Ghana (20 MW), the Ivory Coast Electricity Company (10-15 MW), Contour Global in Togo (30 MW) and the Nigerian Transmission Company (200 MW).[9]

In addition to CEB's capacity, the Benin Electric Energy Company (SBEE) operates an additional 221 MW of thermal power capacity, including 80 diesel generation sets of 1 MW each.[6] However, not all of it is in operation.[6] In 2015, domestic electricity generation in Benin stood at 323 GWh, of which 211 GWh was produced by public power plants and 112 GWh by self-producers.[5]

In 2016, 41 per cent of the population of Benin had access to electricity. The rural electrification rate was 18 per cent and the urban electrification rate was 71 per cent (Figure 2).[12] Electrification programmes are overseen by the Benin Agency for Rural Electrification and Energy Management (ABERME).[9]

Figure 2.
Electrification rate by source in Benin (%)



Source: World Bank[15]

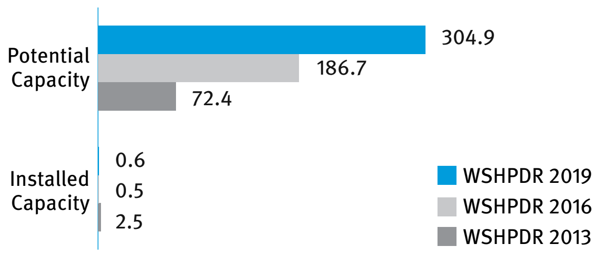
One of the key development objectives for Benin is increased electricity production. To achieve this, the Government plans to install a new dam, a 147 MW hydropower plant at Adjarala and the 120 MW Maria-Gleta dual (oil/gas) thermal power plant in Porto Novo.[10,13] The Adjarala hydropower plant was expected to be completed by 2019. However its completion has been delayed. The construction of the Maria-Gleta thermal power plant was launched in October 2017 and is expected to be completed in 2021.[14] The installation of these two plants would nearly triple the existing installed capacity.

In June 2015, the Government and the Millennium Challenge Corporation signed a power compact of US$375 million to improve the country's power sector. A total of US$136 million will be used to increase domestic generation capacity, adding 45 MW of solar PV generation, rehabilitating 32 MW of thermal and 1 MW of run-of-river hydropower capacity. A total of US$46 million will be used to increase the off-grid electrification rate in rural areas that are currently without access.[6,9,15]

Small hydropower sector overview

The official definition of SHP in Benin is 10 MW to 30 MW. However, different documents use alternative limits.[16] For the purposes of this report, the definition up to 30 MW of capacity, in coherence with the official definition, will be used. Compared to the *World Small Hydropower Development Report* (*WSHPDR*) *2016*, the installed capacity increased by 100 kW, while the potential increased by 118 MW (Figure 3). Both changes are due to access to more accurate data.

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



Source: Millenium Challenge Corporation,[6] *WSHPDR 2016*,[10] *WSHPDR 2013*,[17] ECREEE[18]

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

Hydropower in Benin has a great potential. The country has demonstrated an interest in large-scale hydropower, but there is also potential with small and micro-hydropower units. With a regard to large hydropower, the Nangbeto plant on the Mono River currently provides 65 MW of installed capacity, while the proposed Adjarala project could add 147 MW more.[9]

Currently, Benin has one SHP plant on its territory with a capacity of 0.6 MW, the Yeripao hydropower plant. However, it is currently offline. A number of reports and feasibility surveys have identified a range of potential sites for further hydropower development, ranging from micro to large scale. In 2012, the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) reported that a total of 99 sites with potential capacity up to 30 MW each have been identified through a number of surveys undertaken in the country. The combined potential capacity of these sites is 304.9 MW.[18] Three of these sites (Assante, Dyodyonga and Bétérou) are reported to be in the planning stages.[9] The prefeasibility study for the hydropower site of Bétérou was carried out in 1992. This study was updated in 2015 and the Bétérou upstream site was chosen at the expense of Bétérou downstream for environmental reasons.[9,19]

A more recent assessment of the country's hydropower potential was carried out in 2015 under the ECOWAS Small-Scale Hydropower Programme using Geographic Information Systems (GIS) and identified 5 MW of potential for hydropower less than 1 MW and 90 MW of potential for hydropower from 1 MW to 30 MW. In addition, some 415 MW of hydropower potenatial of all scales was found not attractive for development. However, some of it still could be utilized in multi-purpose schemes.[20]

Renewable energy policy

The Government of Benin is working on developing the RE sector. Various policies and development programmes are going to be implemented. These include:

- The valorization of hydropower potential through developing SHP plants where potential hydropower sites were identified within the rural electrification framework;
- The development and promotion of other RE sources (wind and solar power) within the framework of projects carried out by the Government or by private investors;
- The development and promotion of modern biomass through raw agricultural materials (sorghum, sugarcane).[9]

The strategy for the promotion of biofuels in Benin was adopted by the Government on 28 April 2012. Under this strategy, Benin could develop a production capacity of 1,150 million litres of ethanol and 229 million litres of biodiesel per year by 2025 to cover the domestic market. It could also include 10 per cent blends of bioethanol with petrol, as well as biodiesel with diesel, and substitute 15 per cent of wood energy in households with ethanol.[9,21] In order to promote and develop these policies, the Government created the National Agency for the Development of Renewable Energies (ANADER). A feasibility studies phase conducted by ANADER was completed in 2015, and the country has moved on to finalizing a draft bill on biofuels.[9,22]

Barriers to 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 buyback 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.[9]

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1.5.2 Burkina Faso

International Center on Small Hydro Power (ICSHP)

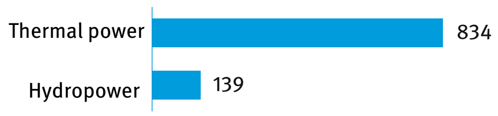
Key facts

Population	19,193,380[1]
Area	274,220 km^2[2]
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.[3] April has the highest average temperature at 32.1 °C, and the lowest average temperature is in January, at 25 °C.[4]
Topography	Burkna 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 savana in the north that gradually becomes sparse forests in the south.[5] 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.[6]
Rain pattern	The Sahelian zone receives less than 600 mm average annual rainfall; the North-Sudanian zone receives an average annual rainfall between 600 and 900 mm; and the South-Sudanian zone receives an average annual rainfall in excess of 900 mm.[3] Rainfall is the heaviest in August, with an average of 230.5 mm, while the average annual precipitation is 816 mm.[4]
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.[5]

Electricity sector overview

At the end of 2016 the total electricity produced in Burkina Faso reached 973 GWh. The country is still highly dependent on electricity imports from Cote d'Ivoire, Ghana and Togo, importing approximately 630 GWh (2016).[16] Figure 1 below offers more information on the electricity generation by source.

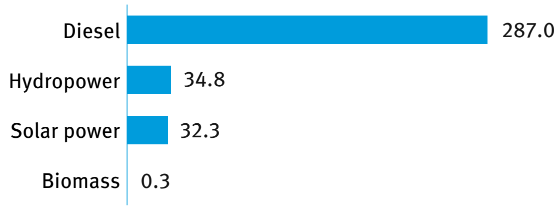
Figure 1.
Annual electricity generation by source in Burkina Faso (GWh)



Source: ARSE[16]

In 2017, the total installed capacity in Burkina Faso was 354 MW. The majority of the generation came from diesel (Figure 2).[7,8] The installed capacity decreased by about 20 per cent compared to the *World Small Hydropower Development Report (WSHPDR) 2016*. This was due to the reduction of heavy fuel oil plants and partially due to data inaccuracies. The operational power plants include 287 MW from diesel power plants, two solar power plants with a combined capacity of 34.8 MW (completed in 2017), 34.28 MW from hydropower plants and 0.28 MW from biomass.[7,8]

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



Source: ECREEE,[8] World Bank[8]

Electricity loss through distribution and the sector's own use amounted to 241.8 GWh.[11] The electricity demand of the country is constantly increasing and there are several projects planned to improve the supply (Table 1). In 2018, a new hybrid solar PV plant with a capacity of 15 MW was commissioned at the Essakane mining site.[23]

The energy sector in Burkina Faso is controlled by the Ministry of Mines and Energy, General Directorate for Energy, with Autorité de Réglementation du Secteur Electricité as the electricity sector regulator. Société Nationale d'Electricité du Burkina Faso (SONABEL) is the state-owned utility responsible for electricity in urban and semi-urban areas. SONABEL and the Electrification Development Fund (EDF) are the two companies which provide electricity generation and supply. SONABEL represents Burkina Faso in the West African Power Pool, which is connecting and integrating regional power systems in the Economic Community of West African States (ECOWAS) region.[14]

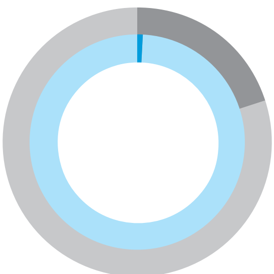
Table 1.
Planned projects Burkina Faso

Title	*Capacity installed (MW)*	*Generation type*	*Connection*
Dedougou 2	15.0	PV solar	Ongrid
Dori 2	15.0	PV solar	Ongrid
Fada Ngourma 2	10.0	PV solar	Ongrid
Kodeni	17.0	PV solar	Ongrid
Pa	17.0	PV solar	Ongrid
Patte d'Oie	6.0	PV solar	Ongrid
Semafo Windiga Energy	20.0	PV solar	Ongrid
Zano	11.0	PV solar	Ongrid
Zina	20.0	PV solar	Ongrid
Samandeni	2.5	Small hydropower	N/A
Total	**133.5**		

Source: SONABEL[11]

Burkina Faso is one of the least electrified countries globally.[12] However the electrification rate has been steadily increasing since 2010. As of 2016, 20.3 per cent of the population had access to electricity. In urban centres, the electrification rate was 58.1 per cent, while in rural areas it was only 1.5 per cent.[10] This is shown in Figure 3.

Figure 3.
Electrification rate in Burkina Faso (%)



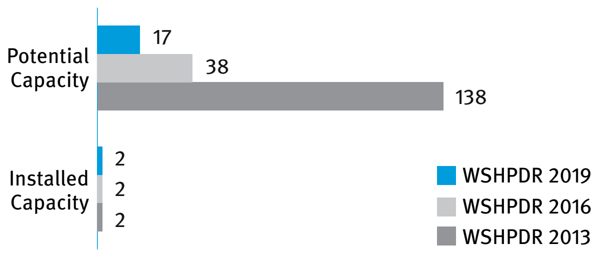
Source: IEA[10]

The Action Agenda of the country describes the objectives of Burkina Faso, envisaged by the Government, which are to reach 95 per cent electrification in urban areas, 50 per cent in rural areas and 65 per cent nationally.[13] The average selling price in 2015 was 121.69 CFA francs per kWh (approximately 0.22 US$). This was still below the cost per kWh of 138.77 CFA franc (approximately 0.25 US$), which represents a loss of 17.07 CFA franc (approximately 0.03 US$) for each kWh sold. This situation is linked to the fact that SONABEL did not benefit from an equilibrium subsidy following the non-readjustment of electricity sales tariffs.[11]

Small hydropower sector overview

There is no official definition of small hydropower (SHP) in Burkina Faso, however SONABEL has used the limits set in Table 2 in official documents. In order to facilitate data comparison, small hydropower will be considered as plants up to 10 MW. Burkina Faso has a total of five small hydropower plants and five pico-stations. The known ones are Niofila (1.68 MW) and Tourni (0.60 MW). Therefore, according to the *World Small Hydropower Development Report* definition, there are ten small hydropower plants in total, with up to 10 MW installed capacity, including the two mentioned above. The total SHP installed capacity in the country is 2.28 MW, the statistic remaining the same from the *WSHPDR 2013* to *WSHPDR 2019*. Small hydropower potential has been once again significantly downgraded to reflect more accurate data, as a consequence of feasibility studies in the region. According to the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), SHP potential for plants under 10 MW is estimated at 17 MW, 1 MW potential for plants below 1 MW (pico-, micro- or mini-hydropower plants) and 16 MW for projects larger than 1 MW.[14,17]

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



Source: *WSHPDR 2013*,[18] *WSHPDR 2016*,[14] ECREEE[17]

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

Another 2.5 MW small hydropower plant, Samandeni, is planned by the Government of Burkina Faso.[19] The Samandeni dam has already been constructed, and the installation of the plant is reported to be underway. At the end of 2015 the Government of Burkina Faso expressed its interest to conduct feasibility studies for the development of another three hydropower plants – the 5 MW Gongourou plant, 5.1 MW Bontioli and 7.8 MW Bon plants. While the Ministry of Energy and Mines declared the aforementioned projects as a priority for sustainable development of the country, no further updates were made with regards to potential commencement or progress of this initiative.[20]

Most of the hydropower projects planned or under construction are located on the Black Volta.[9] Table 2 offers more information with regards to the governmental initiatives in the sector.

Table 2.
Planned hydropower projects in Burkina Faso

Name of project	*Potential capacity (MW)*	*Status*
Samendeni	2.5	under construction
Bagre Aval (II)	15	planned, under study or potential sites
Bonvavle	N/A	planned, under study or potential sites
Bougouriba	12	planned, under study or potential sites
Folonzo	N/A	planned, under study or potential sites
Poni	N/A	planned, under study or potential sites
Noumbiel	62	planned, under study or potential sites
Ouessa	16	planned, under study or potential sites

Source: IJHD[9]

Renewable energy policy

According to the National Strategy, achieving a sustainable production of wood energy as well as improving the development and search of alternative energy sources are priorities of the Government of Burkina Faso. Facilitating better access to electricity for the country's citizens was emphasized in the National Strategy, the target being set at 100 per cent electrical energy access in urban areas and 49 per cent in rural areas by 2020. It is predicted that the Samendeni small hydropower plant will generate 16 GWh/year by 2020.[21]

Information in the field of renewable energy policy in Burkina Faso is enclosed in the Strategy for Accelerated Growth and Sustainable Development (SCADD) and 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 also mentioned reaching 95 per cent access to electricity, 50 per cent in rural areas respectively by 2030. The same action plan envisages Burkina Faso reaching 50 per cent renewable energy in the electric mix by 2030, excluding biomass production.[22]

Barriers to the small hydropower development

There are multiple barriers with regards to small hydropower development in Burkina Faso. Most relevant ones are outlined below.

- Access to water as well as unpredictable climate conditions; droughts affect the regular flow of rivers and negatively influences the profitability of potential SHP projects.
- The Government of Burkina Faso has mainly focused on solar power development, in recent years, as it is seen as a more sustainable and profitable solution, small hydropower dissemination not being 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.[14,16]

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1.5.3 Côte d'Ivoire

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

Key facts

Population	24,294,750[1]
Area	322,632 km[2]
Climate	There are three main climatic regions in Côte d'Ivoire – the equatorial coast in the south, tropical forest in the middle and semi-arid savannah in the north. The average temperature is between 25 °C and 30 °C, and temperatures can range from 10 °C to 40 °C. 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.[2,18]
Topography	The country 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 to 350 metres.[3,18]
Rain pattern	The south has variable rainfalls between 2,100 mm to 2,500 mm. The middle central region has lower rainfalls of approximately 1,100 mm. The north is subject to a single rainy season 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 characterised by a nine-month rainy season from February to October, with rainfall between 1,600 mm and 2,300 mm.[4,18]
Hydrology	The river system of Côte d'Ivoire has four main basins – the Cavally (700 km long with a drainage basin of 15,000 km²), the Sassandra (650 km long with a drainage basin of 75,000 km²), the Bandama (1,050 km long with a drainage basin of 97,000 km²) and the Comoé, 1,160 km long with a drainage basin of 78,000 km².[2,5] There are also a number of small coastal rivers, namely the Tabou, San-Pedro, Niouniourou, Boubo, Agnéby, Mé, Bia and Tanoé, and other smaller rivers such as the Gbanhala, the Baoulé, the Bagoué, the Dégou, the Kankélaba, the Koulda, the Gbanlou, the Gougoulo and the Kohodio.[6,18]

Electricity sector overview

Biomass dominates the energy sector, 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.[18] At the end of 2016, electricity sector provided 2,199 MW of installed and available capacity to the interconnected electricity grid. Generation was from two main sources – hydropower, contributing 879 MW (approximately 40 per cent) and thermal power plants, contributing 1,320 MW (approximately 60 per cent) (Figure 1). The three following Independent Power Producers (IPPs) developed 1,220 MW, or more than 92 per cent of the total thermal power plant capacity – CIPREL (569 MW), AZITO (441 MW) and AGGREKO (210 MW). There are also 51 remote stations with generators running on diesel that supply some localities from mini-grids.[8] The installed capacity of these generators is 6,446 kVA or approximately 5.15 MW.

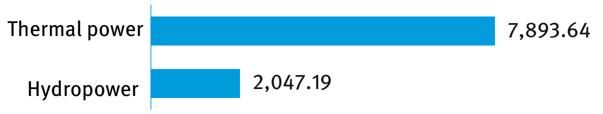
Figure 1.
Installed electricity capacity by source in Côte d'Ivoire (MW)

Source: CIE[8]

In 2017, the total electricity generated from all sources was 9,948.16 GWh. This comprised 2,047.19 GWh generated from hydropower, 7,893.64 GWh from thermal plants (Figure 2) and 7.33 GWh from the remote stations. Electricity exports to countries in the local region amounted to 1,246.6 GWh.[8]

The country has 8,513 localities among which 4,614 were electrified by the end of December 2017. This represented a coverage rate of 54 per cent, higher by approximately one percentage point in comparison to 53 per cent in 2016. In terms of access, 82 per cent of the population living in an electrified area had access to electricity, which is also one percentage point higher than in 2016.[5] Access to electricity as percentage of the whole population was 64 per cent in 2016, roughly 50 per cent higher than in 1990, and is continuously increasing.[17]

Figure 2.
Annual electricity generation by source in Côte d'Ivoire (GWh)



Source: CIE[8]

The number of subscribers to the low voltage electrical service increased by approximately 16 per cent between December 2016 and December 2017 from 1,626,653 to 1,892,711.[5] Based on these data it is estimated that households with access to electricity was 41 per cent in 2017 compared to 36 per cent in 2016. Within the framework of President Alassane Dramane Ouattara's proposal to make Côte d'Ivoire an emerging country by 2020, access to electricity is a major focus of economic and social policy. Given the importance attached to this issue, several actions are being implemented by the Government. These are supported by the establishment of a new Electricity Code adopted in March 2014.[9]

In an effort to facilitate the electricity connection of a larger number of households, the Government has proposed a set of measures, as part of the Electricity for All Programme (PEPT), which reduces initial fees and spreads out the other costs over several years.[10,18] 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 organisations 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 Authority for Electricity Sector Regulatory (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 (monitoring of compliance with regulations and conventions, arbitration of disputes, protecting the users' interests).[18]

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. This was renewed in 2005 until 2020.[18] Three private operators (CIPREL, Azito Energie and Aggreko) are also involved in the sector as Independent Power Producers (IPPs). They operate thermal power plants fuelled by natural gas supplied by PETROCI-C11 and by Foxtrot International and CNR International through contracts of sale and purchase established with the State. In 2017, the electricity grid had a total length of 50,392 km comprising of low voltage lines measuring 21,233 km, medium voltage (15 kV and 33 kV) lines measuring 24,026 km, and high voltage (90 kV and 225 kV) lines measuring 5,133 km.[8]

The Government has adopted a Strategic Development Plan 2011 – 2030, which covers the development of all sectors including the electricity sector.[11] Within this framework several projects have been planned in regards to electricity generation, transmission and distribution infrastructure. At the energy department level, four master plans have been conceived (generation & transmission, distribution, rural electrification, remote control and automation) with the objective of providing coherent planning of the electricity sector's investments between 2014 and 2030.[12] The electricity base tariffs are fixed by the Government. Tariffs are the same for the entire country regardless of region (Table 1).[13,18]

Table 1.
2017 electricity tariffs in Côte d'Ivoire

Tariff base	*Cost excluding 18 % VAT (CFA Franc/kWh (US$/kWh))*
Moderate household low voltage price (consumption < = 80 kWh by two-month period)*	36.05 (0.072)
Moderate household low voltage price (consumption > 80 kWh by two-month period)	62.70 (0.125)
General household price 10 Amps and more (up to 180 kWh/KVA)	66.96 (0.133)
General household price 11 Amps and more (above 180 kWh/KVA)	58.04 (0.116)
General professional low voltage price (up to 180 kWh/KVA)	86.31 (0.172)
General professional low voltage price (above 180 kWh/KVA)	73.40 (0.148)

Source: ANARE[13]

Note: * Exempt from VAT.

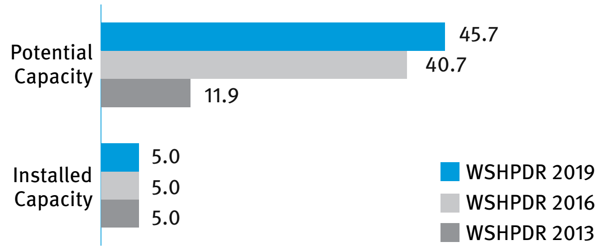
In addition to these base tariffs there are additional taxes such as a fixed fee by two-month period, the fee for rural electrification, the Ivorian Radio Television fee and local taxes that vary according to the electricity subscription and region. Article 2 of Inter-ministerial Order No. 027 of June 28, 2018 stipulates that tariffs shall be revised by March 31 of each year for application on July 1 of that year, on the basis of an indexation formula, developed from price indices reflecting the main cost parameters of the electricity sector.[13] This increase is intended to ensure a sustainable financial balance of the electricity sector and to promote the necessary investments in network expansion and improvement in the quality of electricity supply, including the electrification of all localities by 2020.

Small hydropower sector overview

The official definition of small hydropower is less than 10 MW, as adopted by the General Directorate of Energy (Table 2). The country's 5 MW of small hydropower installed capacity has remained unchanged since the *World Small Hydropower Development Report (WSHPDR) 2013*, however estimated potential has increased by approximately 280 per cent.[14]

There is a single operational small hydropower plant, Grah/Faye, built in 1983 and currently in need of refurbishment. This accounts for 100 per cent of the country's small hydropower installed capacity of 5 MW.[18] The energy generated in 2017 was 0.9 GWh and represented 0.04 per cent of the total hydropower production.[8]

Figure 3.
Small hydropower capacities 2013/2016/2019 in Côte d'Ivoire (MW)



Source: *WSHPDR 2013*,[14] *WSHPDR 2016*,[18] CIE[8]

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

Table 2.
Potential small hydropower sites with capacity less than 10 MW

Sites	*River*	*Estimated output (MW)*	*Estimated annual supply (GWh)*
Haut Bandama	Bandama	7.44	26.06
Ferkessedougou	Lokpoho	7.32	32.94
Aboisso	Bia	6.40	25.28
Korhogo	Lafigué	4.00	17.52
Téhini	Comoé	4.00	17.52
La Palé	La palé	3.50	17.50
Man	Drou	2.56	10.80
Laouguié	Agnéby	2.01	11.60
Fétékro	N'ZI	1.60	12.00
Séguéla	Banoroni	1.50	8.10
Daloa	Sassandra	0.17	0.58
Kassiguié	Agnéby	0.16	0.52
Total		**40.66**	**180.43**

Source: CI-ENERGIES,[5] EDF[15]

Studies conducted in previous years have identified the most promising hydropower development projects. Table 2 consolidates data on sites with an estimated capacity less than 10 MW.[5,15] Based on these studies, dating back to 1979, the available potential capacity for small hydropower is estimated at 45.7 MW, suggesting that less than 11 per cent of Côte d'Ivoire's small hydropower potential has been developed. So far, these are the only studies conducted on small hydropower potential.[15]

Several large hydropower sites have been identified for a progressive development from 2017 to 2025 – Soubré (275 MW), Singrobo (44 MW), Gribo-Popoli (112 MW), Boutoubré (156 MW), Louga (280 MW), Daboitié (91 MW) and Tiboto (180 MW).[10] For hydropower of all sizes there is a total potential for 1.85 GW installed capacity on the four major river basins, two times the current hydropower installed capacity.[18] The Soubré dam (275 MW) has been built and officially put into service on November 2, 2017. Regarding the Gribo-popoli (112 MW) and Singrobo (44 MW) dams, the government has signed concession agreements for their development.

Renewable energy policy

During the period 2013-2030, as part of the Strategic Development Plan 2011-2030, the Ivorian Government aims to increase the share of renewable energy. In addition, Côte d'Ivoire committed itself to the 2015 Paris Climate Conference (COP21) to reduce its emissions of greenhouse gas. This commitment is reflected at the level of the electricity sector, by increasing the share of renewable energy in the energy mix to reach 42 per cent (including large hydropower) in 2030. This policy of development of renewable energy will support the following renewable sources: biomass, hydropower, solar energy and possibly wind energy.

Several projects for electricity generation from renewable energy sources are planned. These include:
- Korhogo Solar 25 MW, Korhogo;
- Canadian Solar (Galilea) 50 MW, Korhogo;
- KFW 30 MW, Odienné;
- Solar (Biotherm Energy) 25 MW, Ferkéssedougou;
- Biomass Cacao 25 MW, Gagnoa;
- Biomass Cotton 20 MW, Boundiali.[16]

Currently, an Off-Grid Development Strategy is underway. It will take into account the problem of access to electricity in the camps. Apart from this, there are no other specific renewable energy policies.

Barriers to small hydropower development

There are multiple barriers to small hydropower. Some of the most significant ones are outlined below.
- The lack of new studies on potential sites: with new studies

undertaken it is likely that the estimated potential of 40.685 MW would be significantly greater.

- 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.

Due to the importance of the electricity sector for the country's economic recovery, more attention is being given to the potential of renewable energy and it is likely that small hydropower will also benefit from this.[18]

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1.5.4 Republic of the Gambia

Philip Stovold, Kaboni Carbon Consultancy Ltd; and International Centre on Small Hydro Power (ICSHP)

Key facts

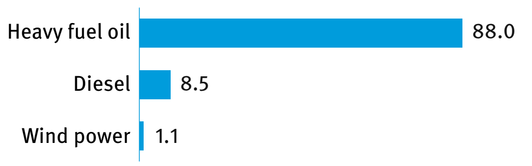
Population	2,100,568[1]
Area	11,300 km^2
Climate	Gambia has a tropical climate, with a distinct rainy season, from June to September, and a dry season, from April to June. During the hottest time of the year, peak temperatures can reach 35 °C, while the cooler coastal regions enjoy an average temperature of 28 °C. From October to December and from January to March, temperatures reach the lowest level – on average below 25 °C at the coast and above 30 °C in the western part of the country.[2]
Topography	The country's territory represents a strip of land that surrounds the Gambia River basin. The country's maximum width is 48 km and the highest point reaches 53 metres above sea level. The Gambia River drops by less than 10 metres from the far eastern border near Fatoto to its mouth at Banjul.[3]
Rain pattern	The mean monthly rainfall during the wet season varies from 150 to 300 mm, between the northern and southern extremes. The rainy season is controlled by the movement of the Inter Tropical Conversion Zone. August is the rainiest month with over 300 mm of rainfall. Annual rainfall ranges between 900 mm and 1,100 mm.[2]
Hydrology	The Gambia River, 470 km, and its tributaries occupy 970 km^2 of permanent surface water area. At the peak of the flood season, the inland surface water area, including the Gambia River, can extend to over 1,965 km^2 (more than 17 per cent of the country's total area). Renewable water resources in Gambia are estimated to be 8 km^3/year, of which 5 km^3 (62.5 per cent) flows into the country from Senegal and the Republic of Guinea. The surface water produced internally is estimated at 3 km^3/year, while annual internal renewable groundwater is estimated at 0.5 km^3.[4]

Electricity sector overview

The main source of energy in Gambia is wood fuel and other biomass fuels, followed by petroleum products and a small fraction of renewable energy sources. The biggest consumers of energy are households and the transport sector, with a steady and consistent increase during the past decade in the consumption of petroleum products. As of November 2017, the installed electricity capacity of Gambia was 99 MW, including 88 MW in the Greater Banjul Area. However, as a result of aging infrastructure and underinvestment in maintenance, by November 2017 available capacity decreased to 54 MW nationwide and to 44 MW in the capital area, while the demand was at approximately 70 MW or up to 150 MW when accounting for suppressed demand.[5]

Two large heavy fuel oil power plants are the main sources of electricity generation in the country, one of these is located in Kotu (40 MW) and the other in Brikama (48 MW).[6] The National Water and Electricity Company of Gambia (NAWEC) also owns six small-scale grids powered by diesel generators with a combined capacity of 8.5 MW and providing electricity in the provinces.[7] Independent power producers developed other projects using renewable energy sources. Wind power plants include the 0.15 MW Batokunku plant and the 0.9 MW Tanji plant.[6,7] Stand-alone solar power projects have a long history in Gambia. Since the first solar power installation in the 1980s, solar photovoltaics systems have been used for telecommunications, lighting and water pumping.[7] However, so far solar power has only been deployed at small scale, and the total installed capacity of solar power plants existing in Gambia is unknown.[5] As of 2016, power generation was at 435 GWh.[8]

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

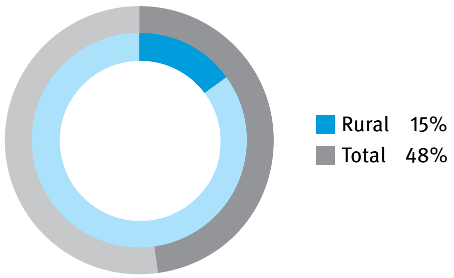


Source: IDA,[5] NAWEC,[6] UNDP[7]

Note: Excluding solar power.

The gap between electricity demand and supply is projected to worsen over the coming decades with the demand expected to exceed 800 GWh by 2020, 1,219 GWh by 2030 and 2,514 by 2050. The situation is further exacerbated by high technical losses on the grid reaching 23 per cent and overall system losses of approximately 30 per cent.[9] The current level of electrification in Gambia is insufficient given the current demand. As of 2011 it was estimated that there were over one million people living without access to electricity.[5] As of 2016, the electrification rate was at 48 per cent, with 60 per cent in urban areas, while only 15 per cent in rural areas (Figure 2).[10] Electrification rates also vary across regions of the country.[9] This implies that there is still a significant potential for growth in the energy market.

Figure 2.
Electrification rate in Gambia (%)



Source: The World Bank[10]

Note: Data as of 2016.

In order to increase access to electricity in rural areas, in 1993 the Government launched the Rural Electrification Project (REP), which established diesel-powered regional grids.[7] Following large-scale blackouts in late 2017, the Government has been taking urgent measures to improve electricity supply. In particular, the Government signed a contract with the Turkish Karpowership to provide a 36 MW heavy fuel oil-power Karadeniz Powership, which was connected to the national grid in May 2018 and will feed 30 MW into it for two years.[11] Furthermore, the Government published calls for investment into power plant projects, including seven solar power systems with a combined capacity of 115 kW.[12]

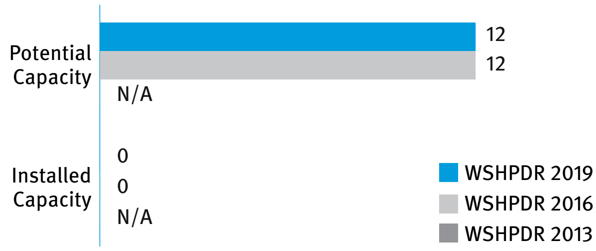
In Gambia, all requests to review the electricity and water tariffs must be carried out according to the Public Utilities Regulatory Authority (PURA) Electricity and Water Retail Filing Guidelines. Since 2012, Gambia has had the following electricity tariffs: up to 300 kWh the tariff is 9.10 D/kWh (0.19 US$/kWh), from 301 to 600 kWh the tariff is 9.45 D/kWh (0.20 US$/kWh) and from 601 to 1,000 kW it is 9.70 D/kWh (0.21 US$/kWh).[13]

Small hydropower sector overview

Small hydropower (SHP) is defined hydropower plants with capacity as up to 30 MW. As of 2018, there was still no installed capacity of SHP in Gambia, while SHP potential was estimated to be 12 MW for plants up to 10 MW.[5,9,15,16] Compared to the results of *the World Small Hydropower Development Report (WSHPDR) 2016*, both installed and potential capacity remained unchanged (Figure 3).

As of March 2017, hydropower played no role in electricity generation in Gambia, as there were no hydropower plants in the country.[15] However the Gambia River Basin Development Organization (OMVG), a regional organization seeking to promote energy sharing and improved quality of the power supply in Gambia, Guinea, Guinea-Bissau and Senegal, issued a tender for feasibility, environmental impact and engineering studies in 2017 for the installation of a 20 MW hydropower plant in the Saltinho area, on the Corubal River in central Guinea-Bissau. The project is to receive the technical and financial support of a number of organizations, including the African Development Bank (through the Sustainable Energy Fund), the United Nations Fund for Industrial Development, the Economic Community of West African States (ECOWAS) and the Austrian Development Bank. [17] Another OMVG project is the 128 MW Sambangalou hydropower plant to be constructed in Senegal on the Gambia River. The plant is expected to generated 402 GWh per year.[18]

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



Source: IDA,[5] *WSHPDR 2016*,[9] *WSHPDR 2013*,[14] GIS,[15] World Energy Council[16]

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

Renewable energy policy

The Government has the monopoly over electricity transmission and distribution. Following the 2004 Electricity Act, the energy market has been partially liberalized and currently there is one independent power producer (IPP) in the country. As for renewable energy (RE), the 2013 Renewable Energy Act established tariffs and net-metering for renewable energy as well as established the Renewable Energy Fund.[7] The Renewable Energy Act also established tax incentives for operators of facilities using RE resources for both power and non-power applications. According to the Act, for 15 years from the date of commissioning, projects producing electricity from RE resources are exempt from corporate and value-added tax. The Act also called for the introduction of a feed-in tariff (FIT) system, to boost the development of RE sources.[9]

Besides hydropower, other RE sources that have a significant potential in the country are solar, wind and biofuels. As for solar power, Gambia could produce 4 kWh per square meter per day according to its potential. Wind power has a potential in the coastal area and especially in the months of January and May. It is also estimated that crops (for example, groundnuts) could be used for biofuel production.[19] Gambia is also committed to the Nationally Appropriate Mitigation

Actions for Rural Electrification with Renewable Energy to develop access to electricity through the small-scale, off-grid and stand-alone projects.[7]

In March 2019, it was announced that Gambia would receive EUR142 million (US$160 million) from the European Investment Bank, the World Bank and the European Union for the construction of a new solar PV plant at Jambur as well as new power transmission and distribution infrastructure. The scheme is expected to increase the country's energy supply by one fifth and transform electricity access in rural communities.[25]

Barriers to small hydropower development

The main challenges affecting the development of small hydropower in Gambia are:

- High cost of electricity generation due to the current state of technology inhibits the development of small hydropower.[20]
- Climate change is highly influencing the potential for small hydropower development in the country.[20]
- A framework for IPP and RE projects to scale up on a commercial level is still not fully functioning.[9]
- The regulatory and permitting system has not been fully developed yet and the licensing pathway remains unclear.[9]
- Long and complex tariff and power purchase agreement negotiations for generation and distribution licences sometimes take years without achieving the final conclusions.[9]
- Lack of rules on connection to the grid for RE projects.[9]

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1.5.5

Ghana

John Kobbina Arthur, Independent Energy Consultant; and International Center on Small Hydro Power (ICSHP)

Key facts

Population	29,265,634[1]
Area	238,533 km^2[1]
Climate	The climate is tropical but relatively mild for the latitude. With the exception of the north, there are two rainy seasons (April to June and September to November). Average temperatures range between 21 °C to 32 °C. In most areas, temperatures are highest in March and lowest in August. No temperature lower than 10°C has ever been recorded in Ghana.[2]
Topography	The country encompasses flat plains, low hills, and a few rivers. The Volta Basin takes up most of central Ghana while the hilly Akuapim-Togo ranges are found along the country's eastern border, home to the country's highest point, Mount Afadjato at 885 metres.[2]
Rain pattern	The annual rainfall in the south averages 2,030 mm, but varies significantly throughout the country, with the heaviest rainfall in the south-west, precisely Axim. On average, June is the wettest month, with the rainfall of approximately 225-250 mm.[2]
Hydrology	Almost all the rivers and streams north of the Akuapim-Togo ranges form part of the Volta River system. This includes the Black Volta and the White Volta Rivers, the latter of which is also fed by the Red Volta. The Volta is approximately 1,600 km in length and drains an area of approximately 388,000 km^2. The Black Volta and White Volta meet at the start of Lake Volta, which was formed after the construction of the Akosombo Dam. At 8,485 km^2, it is the world's largest man-made lake. To the south of the Akuapim-Togo ranges are several smaller independent rivers such as the Pra, Tano, Ankobra, Birim, and Densu.[2]

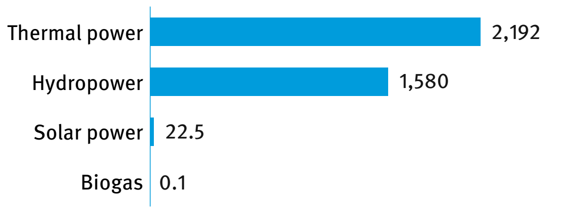
Electricity sector overview

In 2016, Ghana had a total installed capacity of 3,794.6 MW (available 3,481.1 MW). This is made of 2,192 MW (1,995 MW) thermal power plants, 1,580 MW (1,468 MW) from hydropower plants, 22.5 MW (18 MW) from solar power and 0.1 MW from biogas (Figure 1).[3]

The total generation in 2016 was 13,022 GWh. Within power generation, hydropower is contributing 43 per cent (5,561 GWh), and thermal power is contributing 57 per cent (7,435 GWh). The contribution from solar power was 0.2 per cent (27 GWh), whereas the biogas generation was 0.04 GWh (Figure 2). In 2016, there were also 711 GWh imports from Cote d'Ivoire and 187 GWh export, making the net export 324 GWh.[3]

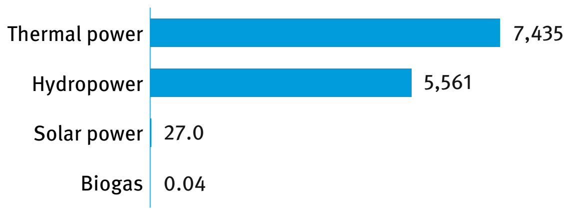
All of the current hydropower capacity comes from three large hydropower plants, Akosombo (1,020 MW), Kpong (160 MW) and Bui (400 MW). A further 179 MW of the hydropower capacity is planned with the addition of three more plants, Juale (87 MW), Pwalugu (48 MW) and Daboya (44 MW).[7] Also, the Energy Commission has identified some additional potential sites on the Black Volta, White Volta, Tano river and the Pra river with a total capacity of about 840 MW that are yet to be developed.[8]

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



Source: Energy Commission of Ghana[3]

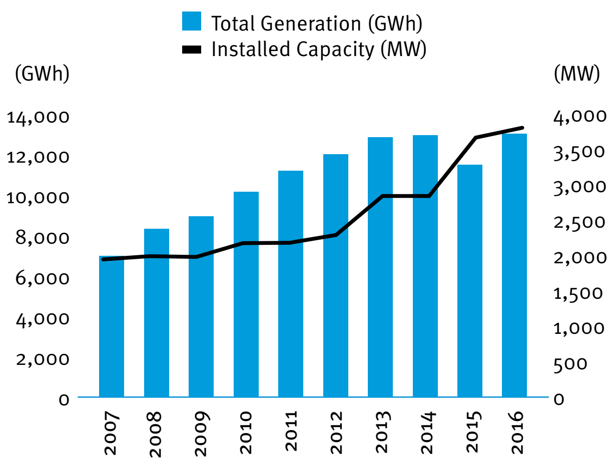
Figure 2.
Annual electricity generation by source in Ghana (GWh)



Source: Energy Commission of Ghana[3]

Ghana pledged to achieve universal access to electricity as far back as 1989 when only 15–20 per cent of the population had access to electricity. The National Electrification Scheme (NES) was established to administer and implement the National Electrification Master Plan which sought to extend electricity to every part of the country by the year 2020. Through programmes like the Self-Help Electrification Program (SHEP), the scheme has been able to extend electricity to about 82.5 per cent of the population as of the end of 2016; rural electrification rate is 72.5 per cent. However, more efforts will be needed to ensure universal access is attained by the year 2020.[9] The electricity generation mix in Ghana has mainly been from hydropower and thermal sources with the country taking steps to introduce significant other amounts of renewable electricity to diversify the current energy mix. Prior to 2016, the only renewable facility feeding directly into the national grid is the 2.5 MW solar photovoltaic plant owned by the Volta River Authority in Navrongo. A 20 MW solar plant owned by BXC Ghana was completed in 2016 to boost the number of renewable energy sources in the generation mix. Also, a 100 kW biogas electricity generation facility was connected to the national grid in 2016.

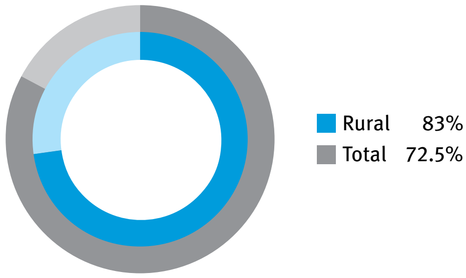
Figure 3.
Electricity generation and installed capacity in Ghana (2007-2016)



Source: Energy Commission of Ghana[3]

In 1990, Ghana implemented the NES with a goal of 100 per cent access by 2020 through six five-year phases, the last of which began in 2015. When the NES was implemented, Ghana had an electrification rate of 28 per cent. As of 2010, it was 72 per cent. The Greater Accra region on the southern coast, home to the capital city of Accra, had the highest electrification rate at 97 per cent. The neighbouring Central region and nearby Ashanti region were the only other regions to have an electrification rate above the national average, both above 80 per cent. The lowest rates of electrification were in the Northern, Upper East, and Upper West regions, all of which were below 50 per cent. In the Upper West region, it was as low as 40 per cent. The NES is complimented by the SHEP, which aims to speed up the electrification process by encouraging towns and villages to help contribute to the cost of electrification. To qualify for the SHEP program, communities must be located within 20 km of an existing 33 kV, 34.5 kV or 11 kV source of supply, be willing and able to procure and erect the required number of standard low voltage poles and have at least 33 per cent of houses in community wired and ready for service.[11]

Figure 4.
Electrification rate in Ghana (%)



Source: Kumi (2017),[9] USAID[10]

The Ministry of Energy is responsible for setting energy policy, including in the power sector. Prior to 2008, the VRA was the state utility responsible for generation and transmission. Distribution had always been the sole responsibility of Electricity Company of Ghana (ECG) until North Electricity Distribution (NED), now the Northern Electricity Distribution Company Limited (NEDCo), was established. NED was formed when the Northern Electricity Distribution operations of the then Electricity Cooperation of Ghana were ceded to the VRA, at the time of extending the national grid beyond Kumasi to the northern parts of Ghana. Distribution is shared between the ECG and NEDCo, a subsidiary of the VRA. Together they satisfy all of the country's electricity demand as well as of some other West African countries. It is expected that NEDCo's responsibilities will eventually be transferred to the ECG to create a single national distribution company.[5]

After the 2005 reforms, the VRA's electricity transmission functions were transferred to the Ghana Grid Company Limited (GRIDCo). GRIDCo has since then been responsible for the operation of the National Interconnected Transmission System, bulk power purchase of electricity from generators and sale to NED, ECG, andEPCL. GRIDCo is also the independent system operator in Ghana.

Ghana has two regulatory entities for the electricity sector. Generation licenses are granted by the Energy Commission, which is also responsible 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 sector (as well as gas and water), including the setting of tariffs. Table 1 gives a breakdown of electricity tariffs for different categories as of March 2018.12 Although under PURC tariffs have been slowly rising they are still below the cost of supply, resulting in the VRA, NEDCo, and ECG being in precarious financial situations. This, in turn, has affected their ability to maintain and expand the system adequately, potentially contributing to the poor service and extended downtime.

Table 1.
Electricity tariffs (GHS/kWh (US$/kWh))

Tariff category	*Rate (GHS/kWh (US$/kWh))*
Residential	
0-50	0.28 (0.059)
51-300	0.56 (0.12)
301-600	0.72 (0.15)
601+	0.80 (0.187)
Non-Residential	
0-100	0.68 (0.14)
101-300	0.68 (0.14)
301-600	0.72 (0.15)
601+	1.14 (0.24)
Service Charge (GHS/month)	10.55 (2.21)
SLT-Low Voltage	
Maximum Demand Charge (GHS/kVA/month)	59.10 (12.38)
Energy Charge	0.76 (0.16)
Service Charge (GHS/month)	42.21 (8.84)
SLT-Medium Voltage	
Maximum Demand (GHS/kVA/month)	50.65 (10.60)
Energy Charge	0.54 (0.11)
Service Charge (GHS/month)	59.10 (12.38)
SLT-High Voltage	
Maximum Demand (GHS/kVA/month)	50.65 (10.60)
Energy Charge	0.54 (0.11)
Service Charge (GHS/month)	59.10 (12.38)

Source: Public Utilities Regulatory Commission[12]

Effective since 15 March 2018, the electricity tariffs summarized in Table 1 have been approved for customer categories, depending on their level of consumption; while Table 2 shows the percentage reduction compared with previous existing tariffs. On the PURC website, it is possible to check tariffs in detail.[12]

Table 2.
Summary of average percentage reduction in tariffs approved by the Public Utilities Regulatory Commission

Customer category	*PURC approved average percentage reduction*
Residential Customers	17.5 %
Non-residential Customers	30 %
Special Load Tariff Customers (LV, MV & HV)	25 %
Mines	10 %

Source: Public Utilities Regulatory Commission[12]

Small hydropower sector overview

Ghana defines the small-scale hydropower (SHP) as up to 1 MW with the medium-scale ranging from 1 MW to 10 MW, and the large-scale between 10 MW to 100 MW. All the following sites in the country such as Kokuma Falls, Randall falls, Wurudu falls, Kintampo falls, Tsatsadu falls and Kwanyaku are potential locations for sitting grid-connected SHP plants. There are currently no existing SHP plants in Ghana, although it is estimated that there is a potential of at least 17.4 MW from sites below 10 MW (Figure 5).[16] The change in the estimate of the potential capacity compared to the *World Small Hydropower Development Report (WSHPDR) 2016* is due to access to more accurate data.

Figure 5.
Small hydropower capacities 2013/2016/2019 in Ghana (MW)

Source: Energy Commission of Ghana,[3] *WSHPDR 2013*,[4] *WSHPDR 2016*,[5] ECREEE[16]

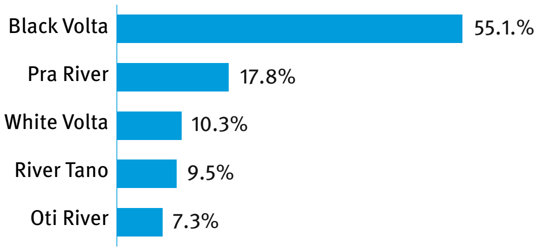
Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

The total hydropower potential of Ghana is estimated at 2,420 MW.[23] A number of studies provide various estimates of the 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.[16] A report by the Energy Foundation suggests there is potential for 2.24 MW from 12 sites less than 1 MW.[14] Based on these studies, it can be assumed that the total SHP potential up to 10 MW in the country is at least 17.4 MW.

For the sites up to 30 MW, a report by the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) estimates a total of 85 potential sites with a total potential capacity of around 110 MW.[16] The potential for hydropower between 10 MW and 100 MW is estimated at approximately 1,237 MW. According to the Ministry of Energy's estimate, the majority of medium hydropower potential is to be found in the Black Volta River basin. This constitutes approximately 55 per cent of the total (Figure 6).[23]

In 2015, the Small Hydro Development Corporation Ltd, a Ghanaian independent power producer, signed a US$ 164 million agreement with the ECG to develop three hydropowerplants with a combined capacity of 42 MW on the Ankobra River with work set to begin in 2017, but works have not yet started as of April 2018.[17] Feasibility studies for three potential sites with total estimated capacity of 200 MW have also been completed.[18] There are a number of incentives towards rural electrification as a part of the NES including the SHEP. Moreover, the Government of Ghana is prepared to enter into public-private partnership with potential investors.

Figure 6.
Share of 10 MW – 100 MW hydropower potential in Ghana by river system (%)



Source: Seth & Modjinou[23]

Renewable energy policy

The Government's Sustainable Energy for All Action Plan 2012 sets a target of 10 per cent of the energy mix from renewable energy (RE) and reduce the share of combustible RE sources (wood fuel) to below 50 per cent by 2020.[21] This is to be achieved through the provision of both grid-connected and off-grid facilities with the announcement that the Government had invested US$ 10 million to finance off-grid facilities for communities which could not be connected to electricity by virtue of their location.[20] To achieve this, the Government has specific targets to increase capacity from renewable energy sources by 2030 (Table 3). For example, feasibility studies of the development of medium hydropower potential sites have been carried out for three to six potential sites. The ambitious target of the Government of 10 per cent penetration is in line with the United Nations Sustainable Development Goals agenda (2030).[5]

Table 3.
Renewable energy installed capacity targets by 2030

Programme	*Preliminary target installed capacity by 2020 (MW)*
Feasibility study and the development of medium hydropower potential sites	200 - 300 (3-6 potential sites)
Utility Scale Wind Part	150 - 500
Utility Scale Biomass & W2E (Waste to Energy) power plants	70 - 150
Utility Scale Solar Farms	150 - 300
Distributed Grid Connected RE generation through Net/metering (solar, wind, biomass, hydropower)	40 - 200

Source: Ahiataku-Togobo[18]

The principle legislation regarding renewable energy is the 2011 Renewable Energy Law, Act 832, which aims to provide for the development, management, and utilization of renewable energy sources.[19] In general, Act 832 seeks to provide the fiscal incentives and regulatory framework to encourage private sector investment in the national RE sector. Key provisions include a feed-in tariff (FIT), and Renewable Energy Purchase Obligation (REPO) schemes.[5]

The Renewable Energy Act gives the Public Utilities Regulatory Commission the responsibility to set FITs for RE technology. As of October 1, 2016, FIT of GHS 0.53 (US$ 0.11) per kWh was applied to SHP plants less than 10 MW, which is one of the lowest FITs available for renewable energy sources (Table 4). These rates are in line with the third RE-FIT 2016, Provision for 10 and 20 years and capacity limit subject to grid impact studies.[18]

Table 4.
Guaranteed FIT 10 years vs. 20 years indicative FIT

Type of technology	*Guaranteed FIT 1-10 years GHS/ kWh (US$ cents/kWh)*	*Indicative FIT 20 years GHS/kWh (US$/kWh)*
Biomass (plantation as feed stock)	0.78 (0.17)	0.67 (0.14)
Biomass (enhanced technology)	0.73 (0.16)	0.63 (0.14)
Landfill gas	0.69 (0.15)	0.60 (0.13)
Sewage gas	0.69 (0.15)	0.60 (0.13)
Biomass	0.69 (0.15)	0.60 (0.13)
Wind	0.65 (0.14)	0.57 (0.12)
Solar	0.60 (0.13)	0.51 (0.11)
Hydropower (>10MW and <=100MW)	0.57 (0.12)	0.49 (0.11)
Hydropower (<=10MW)	0.53 (0.11)	0.46 (0.10)
Tidal wave	0.53 (0.11)	0.46 (0.10)
Run-of-river hydropower	0.53 (0.11)	0.46 (0.10)
Geothermal	0.47 (0.10)	0.40 (0.09)

Source: Public Utilities Regulatory Commission,[6] Ahiataku-Togobo[18]

Gazette in Ghana Cedis at GHS 4.64681/USD, 22 May 2018 Interbank Exchange rate - (GAB)

Note: FIT is payable in local currency only at the above exchange rate.

Under the Act, electricity distribution utilities or bulk customers are obligated to purchase a specified percentage of its total purchase of electricity from RE sources with the level to be specified by the PURC in consultation with the Energy Commission.[19]

The Act also established the introduction of net-metering in January 2015 for facilities up to 200 kW allowing for RE generated to be delivered to the local utility in order to offset the cost of electricity provided by the utility.[22] A provision is also made for the establishment of an RE fund to provide financial incentives, subsidies and scientific, technological and innovative research as well as calling for the establishment of a Renewable Energy Authority to oversee the implementation of RE activities in the country. Key programme initiatives are: China, Japan, Israel, India – Human resource capacity development in the RE Sector, Ghana-China UNDP Renewable Energy Technology Transfer Project with support from Denmark.[14] The duties of the Renewable Energy Authority are undertaken by the Renewable Energy Directorate under the Ministry of Energy until the Authority is established.

Barriers to small hydropower development

Key barriers are:

- Lack of funding: High cost for the development of sites, turbine design cost, the investment cost of construction and labour cost as well as inadequate financing of civil works. In some cases, this has already proven to lead to the project abandonment.[8]
- The absence of a regulatory and legal framework for SHP development: There is little or no economic incentives prepared to entice investors to small hydropower. The tariffs (FIT) are not strictly based upon the cost of a generation either and, given the currently low levels of consumer tariffs, it is also unclear how the program will be financed, potentially deterring more risk-adverse investors.
- Lack of SHP awareness, incentives and motivation: The Government of Ghana in conjunction with the Energy Commission and the Public Utilities Regulatory Commission (PURC) has to make available a clear regulation and attractive price for supplying energy into the national electricity grid in order to attract private sector investors and other renewable energy sources investors to invest into the small hydropower energy generation projects.[23]
- Limited local technical expertise in developing SHP projects: The country also lacks personnel that has the skills and technical know-how on small hydropower construction. Especially the designing of the appropriate turbine to fit the area and as well as its management.
- Lack of the information about the potential sites (hydrological data): insufficient information also increases investment risks, especially in the case of unfavourable flow duration curves. In some cases, a particular site could be used to stimulate socioeconomic activities other than power generation, for example, irrigation, tourism, ecological education, a religion which would avoid the displacement of people, animals, and flooding.

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1.5.6 Guinea

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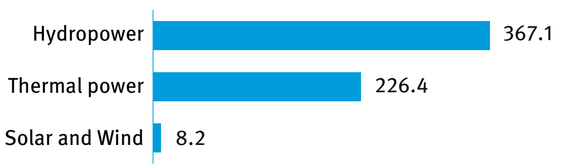
Key facts

Population	12,717,176 [1]
Area	245,857 km² [1]
Climate	Maximum temperatures are reached during March and April. In Koundara temperatures can reach 39 °C, while in Conakry - up to 31 °C. Minimum temperatures are in December-January during the harmattan, the north-east wind. The minimum temperatures are recorded in Fouta (4.1 °C at Labé). The territory can be divided into two regions based on the maximum temperature distribution: the Western lowlands (Koundara and Boké with temperatures of more than 27 °C) and Upper Guinea (Kankan and Siguiri with temperatures of more than 26 °C). For minimum temperatures two main areas are the area of Fouta (with temperatures reaching less than 22 °C in Labé) and the Forested Guinea (with temperatures reaching less than 25 °C from Kissidougou to N'Zénékoré).[2]
Topography	Maritime Guinea is the coastal strip between Guinea-Bissau to the north and Sierra Leone to the south (300 km) and is home to the largest mangroves in West Africa. Central Guinea is a mountainous region, yet the highest peak is in the Guinea Forest region, Mount Nimba at 1,752 metres. Upper Guinea has a low relief (average of 500 metres).[2]
Rain pattern	Maximum rainfall is in Lower Guinea, around the area of Conakry (3,798 mm) and in the Forested Guinea (2,747 mm) in Macenta. The minimum is recorded in the alluvional flatlands in Upper Guinea, along the Niger river and another in the north (Koundara), where the yearly mean rainfalls area lower than 1,115 mm. The absolute record of the country has been registered in 1954 at 5,734 mm.[2]
Hydrology	Rivers follow irregular paths. There are 1,165 registered rivers, 23 river basins, 14 of them are international. The Niger River, for example, flows through 11 countries.[2]

Electricity sector overview

While Guinea has hydropower potential and some of the largest reserves of bauxite, the energy sector has not been developed extensively to pursue sustained development, due in large part to the political instability of the past. In recent years the situation has improved, with development packages implemented by the World Bank, the African Development Bank and others to rehabilitate the electric grid in Conakry as well as to develop other areas.

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

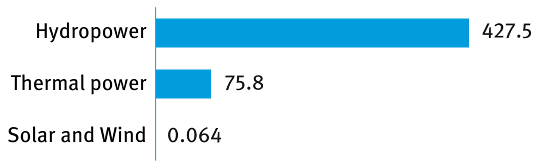


Source: EDG,[3] SE4ALL[5]

Note: Thermal and hydropower data refer to 2016. Data for solar and wind data refer to 2013.

In 2016, the estimated installed capacity in Guinea was 601.7 MW, mainly from hydropower and thermal power plants. Thermal installed capacity was 226.4 MW, however the capacity available was only 91.3 MW. As for hydropower the installed capacity was 367.05 MW and the available capacity was estimated at 320.05 MW (Figure 1).[3] In 2015, the activation of the Kaléta dam (240 MW) increased the available capacity in hydropower.[4] Besides, 18 thermal sites have been installed and three dams capacity have increased, while in the past they could only be used at 50 per cent of their potential.[3] Solar and wind power installations are also present in the country for about a total of 8.21 MW.[5]

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



Source: SIEguinee,[4] SE4ALL[5]

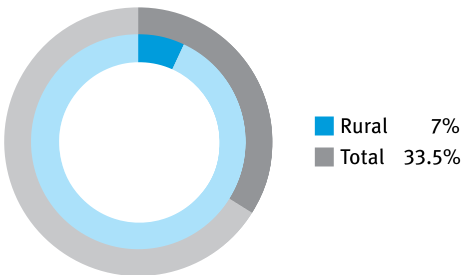
Note: Thermal and hydropower data refer to 2017. Solar and wind data refer to 2013.

As of 2017, the estimated total electricity generation was 503.4 GWh: 427.5 GWh for hydropower, 75.8 GWh for thermal power and about 0.064 GWh for solar and wind power (Figure 2).[4,5]

According to 2018 estimates, the electricity demand which was at 600 MW was not satisfied completely and in 2025 the demand is expected to reach 1,838 MW.[11] Home to the sources of the Niger, Gambia and Senegal Rivers, Guinea boasts one of the highest hydropower potentials in West Africa. However, the country currently utilizes less than 5 per cent of its technically exploitable hydropower potential, which is estimated at 6,100 MW.[6]

As of 2016, the electrification rate in Guinea was approximately 33.5 per cent, with the rate for urban households standing at 82.2 per cent and for rural areas at a mere 6.9 per cent (Figure 3).[7] The Bureau d'Électrification Rurale Décentralisée is responsible for carrying out rural electrification projects.

Figure 3.
Electrification rate in Guinea (%)



Source: World Bank[7]

There are different companies operating in the country. Holding Guinée has an exploitation agreement of 100 MW, the Chinese CWE for the exploitation of Kaléta (240.5 MW), and Electricité de Guinée is the company in charge of pulling up again the electricity sector of Guinea within four year.

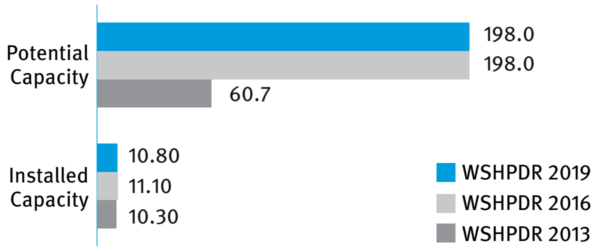
In 2015, with the commission of Kaléta project (240 MW) Guinea reached a milestone. The three-turbine generation station has almost tripled the country's total installment hydropower capacity from 125 MW to 368 MW. This project was completed with the support of the Gambia River Basin Development Authority (OMVG) and cooperation with China international Water and Electric Corporation (CWE), wholly owned subsidiary of China Three Gorges Corporation. Besides, also the Souapiti hydropower project entered the construction phase, by 2020 it should contribute to advance Guinea's strategic goal to become a net power exporter thanks to an addition of 515 MW.[6]

Small hydropower sector overview

Guinea does not have a small hydropower definition. According to the definition of CEDEAO/ECREEE, there are pico, mini, micro, small hydropower plants and large dams. For the purposes of this report, the upper limit will be 10 MW.

The total hydropower theoretical potential is 6,100 MW and power generation 26,000 GWh, whilst guaranteed potential is 19,300 GWh. As of 2017, the total SHP installed capacity is 10.8 MW, while the potential capacity has remained unchanged (Figure 4). The SHP installed capacity has slightly decreased as the Seredou plant is not in operation anymore (Table 1).[4]

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



Source: SIEguinee,[4] *WSHPDR 2013*,[9] *WSHPDR 2016*[10]

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

Table 1.
Installed capacity of small hydropower plants (MW)

Plant name	*Capacity (MW)*
Banéah	5
Kinkon	3.5
Tinkisso	1.7
Loffa	0.2
Samankou	0.4
Total	**10.8**

Source: SIEguinee[4]

Table 2.
Planned small hydropower sites (MW)

Site name	*Capacity (MW)*
Touba	5-10
Lokoua	6.0
Founkéya bankô	4.0
Daboya	2.8
Fôkô	2.5
Bagata	1.2
Total	**22-27**

Source: SIEguinee[4]

Currently, the Energy and Hydropower Ministry of Guinea has designated four micro-hydropower projects as having priority – Fôkô (2.5 MW), Bagata (1.2 MW), Founkéya bankô (4 MW) and Lokoua (6 MW). The elaboration of the terms of the reference studies for implementation is underway. The activation of the plants is estimated to occur in 2016-2020.[4] Other projects for small hydropower include the Daboya site (2.8 MW), a dam with multiple purposes (electricity, irrigation, and potable water) that is looking for funds, the Touba hydropower plant, which should have between 5 and 10 MW in capacity, and Hydro Escott, which has carried out the preliminary studies (Table 2).[4]

Renewable energy policy

The Government of Guinea aims to promote solar and hydropower and become a major electricity producer by 2020. Policies in Guinea regarding renewable energy (RE) were started within the framework of reducing poverty according to the Targets of the Millennium Development Goals 2015. In 2015, the Guinean Government has also issued the Document de Strategie de Reduction de la Pauvrete and the Lettre Politique de Development du Secteur de L' Energie, to fight poverty and develop the energy sector. These highlighted the following targets:

- Develop 20 mini- and micro-hydropower plants before 2025;
- Develop 150 electrification systems, in the form of public-private partnerships;
- Develop 11 hydropower sites (Kassa B, Poudaldé, Gozéguézia, Souapiti, Amaria, Fomi, Kourou Tamba (Diaoyal), Bouréya, Kogbédou, Diaraguéla, Morisananko) mostly in the form of public-private partnerships. These sites have a potential of 1,598 MW and will generate approximately 8,630 GWh.

Barriers to small hydropower development

Small hydropower plants have been an important part of the electricity sector, justified by the importance of the development of the industry and mine sector. Guinea has a wide range of hydropower resources which can be developed in a sustainable manner to provide grid connected and non-connected areas with the needed electricity supplies.[4] However, improvements must be made in the following areas:

- Optimization of current capacity: it would be recommended to carry out more studies on the development strategy of the hydropower potential.
- Grid network: new transmission lines could connect mountain and forest areas with electricity, besides a better maintenance of the lines could ensure a better transmission.
- Capacity building: the lack of adequate infrastructure for research, planning, implementation and operation, including training of staff and supervisors of maintenance services of RE technologies in general and SHP in particular.
- Legislation: lack of relevant legislation. There is the need to develop suitable and adapted legislation promoting the use of renewable energies including SHP as well as related implementation and creation of incentives.
- Financial mechanisms: lack of financial resources due to the complex permitting and licensing process for RE projects, with negative impact on the indices of development of RE and on technology transfer.
- EDG company: the improvement of the management of the public company in charge of electricity could have a better return on investments and develop a better infrastructure.[10,11]

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1.5.7 Liberia

M. Hady Sherif, Center for Sustainable Energy Technology; and International Center on Small Hydro Power (ICSHP)*

Key facts

Population	4,731,906[1]
Area	111,370 km[2]
Climate	The equatorial position of Liberia puts the sun almost overhead at noon throughout the year, giving rise to intensive heat in all parts of the country. Its temperatures range from 27 °C to 32 °C during the day and from 21 °C to 24 °C at night. Higher altitudes near the Guinean border in the north have a cooler climate.[2]
Topography	Characterized by mostly flat coastal plains rising to rolling plateaus and mountains in the north-east, the highest elevation is the northern highlands, which includes Mount Wutivi (1,350 metres), the maximum elevation in Liberia.[3]
Rain pattern	There are two seasons: rainy and dry. The rainy season lasts from April to October. Average annual rainfall along the coastal belt is over 4,000 mm and declines to 1,300 mm at the forest-savannah boundary in the north. The months of heaviest rainfall are June, July and September. Overall annual rainfall ranges from 2,000 to 4,000 mm, with an average of 2,372 mm.[3]
Hydrology	Water resources cover an estimated 200 km^2 of the surface area in Liberia. There are six major rivers flowing north to south. The drainage basins cover approximately 66 per cent of the country. These rivers are the Mano, St. Paul, Lofa, St. John, Cestos and Cavalla. Short coastal watercourses have drainage basins covering approximately 3 per cent of the country. They include the Po, Du, Timbo, Farmington and Sinoe Rivers.[3]

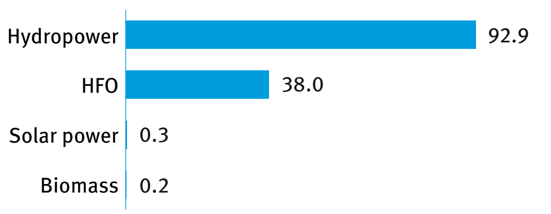
Electricity sector overview

The installed electricity capacity of Liberia in 2017 stood at approximately 131 MW, of which hydropower accounted for almost 71 per cent and heavy fuel oil (HFO) for almost 29 per cent (Figure 1).[4,5,6] The single largest source of electricity is the Mount Coffee hydropower plant, which was constructed in the 1960s but was severely damaged during the civil war. Following the rehabilitation works finished in 2017, the plant's installed capacity reached 88 MW.[7] Before the completion of the rehabilitation works, Liberia heavily relied on 22 1 MW diesel units, which were managed by the utility company Liberia Electricity Corporation (LEC) and supplied electricity to Monrovia. These units have now been decommissioned. In addition to the Mount Coffee hydropower plant, there are also two small hydropower plants: the 4 MW Harbel hydropower plant operated by Firestone Plantation Company and the community-operated 60 kW Yandohun hydropower plant in Lofa County.[5,6]

The capacity of biomass-fired power plants is estimated to be up to 160 kW, while the total capacity of solar power power systems, which are utilized by households, is estimated to be at least 250 kW.[4] The total capacity of self-producers not being serviced by LEC is estimated to be very high – at some 90 MW.[8]

According to the African Statistical Yearbook, the total electricity generation in 2016 was estimated at 113 GWh, slightly above the annual electricity production of 109 GWh in 2015.[9] The Liberia Investment Plan for Renewable Energy indicates that the LEC reports high commercial and technical losses ranging from 25 to 40 per cent.[10,11] The country has a low electrification rate of 20 per cent nationwide and 34 per cent in urban areas. The rural electrification rate is approximately 1 per cent (Figure 2).[12] More than 90 per cent of the population relies on traditional, costly, and inefficient sources of lighting such as dry cell battery-powered lamps, palm oil lamps and small gasoline/diesel-powered generators.[11] Charcoal and firewood are used for cooking and heating and account for 9.5 and 83.8 per cent of the primary energy mix, respectively.[8]

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

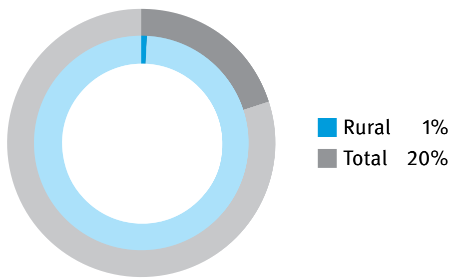


Source: CIF,[4] Renewable Liberia[5,6]

* *WSHPDR 2016* updated by ICSHP

However, in line with the Sustainable Energy for All initiative and the Sustainable Development Goals, Liberia aims to improve rural electricity access. In particular, the electrification rate for the population outside of the capital city of Monrovia is expected to reach 10 per cent in 2020, 20 per cent in 2025 and 35 per cent in 2030. It is planned to connect at least 2,000 settlements to the national, decentralized or mini-grids by 2030. All county capitals as well as healthcare facilities and secondary schools are planned to be electrified before 2025. Ten largest settlements in every county should be electrified and no county should have less than 15 per cent electrification rate by 2030. Finally, there are plans to establish a credit/subsidy mechanism specifically for the connection of poor and woman-led households.[13]

Figure 2.
Electrification rate in Liberia (%)



Source: World Bank[12]

The country's electricity infrastructure was almost completely destroyed during the 14 years of civil conflict which erupted in 1989. The total pre-war electricity generation capacity was 412 MW, of which 191 MW was provided by the LEC, which served approximately 35,000 customers or 7 per cent of the population at the time. During the conflict, the 64 MW Mount Coffee hydropower plant near Monrovia was destroyed, along with other thermal power plants owned by both Government and private concessions. Public access to electricity subsequently became non-existent. With assistance from international development partners, the post-war elected Government is continuing to rebuild the electricity infrastructure.[11]

The electricity sector in Liberia comprises three key Governmental actors: the Ministry of Lands, Mines and Energy (MLME), the LEC and the Rural and Renewable Energy Agency (RREA). The MLME has an oversight role planning, formulating and implementing policies and regulations. The MLME is part of the board of directors of the LEC and the RREA. The LEC is a public corporation with the mandate to generate, transmit and distribute electricity throughout Liberia. In 2010-2016, the LEC was under a management contract with the Canadian-based Manitoba Hydro International and since January 2018 with the Irish-based ESB International.[11,14] The RREA has been operating since 2010 under an Executive Order issued by the President in response to the National Energy Policy (NEP). Its role is to facilitate and accelerate the economic transformation of rural Liberia by promoting the commercial development and supply of modern energy products and services to rural areas through both community initiatives and the private sector with an emphasis (though not exclusive reliance) on locally-available, renewable resources.[11]

Grid availability is yet to cover the entire capital city, let alone the rural areas. However, World Bank-funded projects, as well as other earlier donor-funded initiatives, are working to extend the grid coverage in the greater Monrovia area and beyond. Rural grid access is limited to the areas so far connected through the cross-border interconnection with Côte d'Ivoire.[11]

Through the support of the United States Agency for International Development (USAID), the Liberia Energy Assitance Programme (LEAP) was implemented, which then established the National Energy Policy (NEP) in 2009. Similarly, through the World Bank Climate Investment Funds' Scaling Up Renewable Energy Programme (SREP), the Investment Plan for Renewable Energy (IPRE) was developed in 2013. The Government has completed and finalized the Least Cost Power Development Plan (LCPDP) and embarked on an Energy Access Plan and Rural Energy Master Plan, among others. Current power generation and grid extension projects include:

- Construction of a total of 48 MW of heavy fuel oil thermal power to compensate for the high seasonality of hydropower;
- Construction of the 225 kV WAPP–CLSG (West Africa Power Pool – Côte d'Ivoire, Liberia, Sierra Leone, Guinea) Regional Transmission Line at US$494 million. Plans are also underway to extend the Monrovia grid and expand outside the capital, as well as to implement SREP in rural Liberia for feasible small-scale hydropower, as well as biomass and solar power projects.[11,15]

Electricity demand forecasts for Liberia have been challenging, given the limited development of power networks in and around Monrovia. Relying on previous forecasting efforts, the LCPDP provides 20-year electricity demand projections for three different scenarios (base, high and low) including the current unsatisfied demand but excluding the mining sector. This forecast for electricity demand indicates a potential for fast growth at an annual rate of 10 per cent between 2013 and 2023. Peak load is expected to reach 311 MW by 2033 and the corresponding energy demand will be 1,672 GWh. Monrovia is expected to remain the primary load centre accounting for approximately two-thirds of the country's electricity demand. With the inclusion of the mining industry, projected demand is estimated to be much higher.[11]

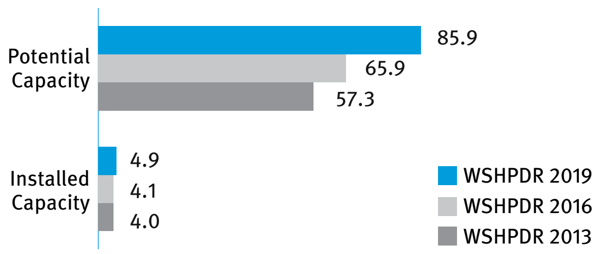
Under the SREP's IPRE, a portfolio of nine mini-grid projects and nine stand-alone solar PV projects totalling 18.1 MW is being considered. The projects consist of one biomass plant of 1 MW, four hydropower plants of 1 MW, three small hydro-solar hybrid systems of 1.5 MW, one biomass-small hydropower hybrid system of 2 MW and nine stand-alone solar PV systems totalling 6.6 MW. Apart from the stand-alone systems, the above projects stand to feed to the LEC grid or CLSG regional transmission line substations so as to, among other things, achieve a geographic balance for electricity provision.[11]

Electricity tariff constitutes fuel adjustment cost, generation tariff and Goods and Services Tax. The LEC tariff is regulated by the board of the LEC. A single tariff is applied for all types of consumers based on a revenue requirement approach, which considers the revenues needed to meet all the utility's operating expenses and capital costs. Tariffs are calculated quarterly, considering the price of equipment, service schedule, maintenance, distribution costs and 20 per cent of technical and non-technical losses. As of December 2017, the LEC tariff was 0.39 US$/kWh. The tariff was decreased from 0.49 US$/kWh in March 2017 in line with the Government's commitment to provide affordable electricity.[16]

Small hydropower sector overview

The definition of small hydropower (SHP) in Liberia conforms to that of the regional body, the Economic Community of West African States (ECOWAS), which is up to 30 MW.[17] The installed capacity of SHP in Liberia is 4.86 MW and the total potential is estimated to be at least 85.88 MW, indicating that approximately 6 per cent has been developed.[5,6,18] Between the *World Small Hydropower Development Report* (*WSHPDR*) *2016* and *WSHPDR 2019* installed capacity has increased by 20 per cent, while estimated potential has increased by approximately 30 per cent (Figure 3). Both changes are due to access to more accurate data.

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



Source: Renewable Liberia,[5,6] *WSHPDR 2016*,[11] ECREEE,[18] *WSHPDR 2013*[19]

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

The current installed capacity of 4.86 MW comes from two plants. One of these is a community-owned 60 kW plant and the other is a private, concession-owned 4.8 MW plant. The 60 kW plant is located in Yandohun, Lofa County in northern Liberia and was rehabilitated and upgraded to that capacity in 2013 by the RREA with funding (US$0.47 million) from the World Bank. Prior to the civil war, this was a 30 kW plant owned by an American PeaceCorp volunteer. The 4.8 MW plant has been operational since before the civil war and is owned and operated by the Firestone Rubber Plantation Company in Harbel, Margibi County.[5,6,11]

The total potential SHP capacity of up to 30 MW is estimated to be 85.88 MW from 30 potential sites.[18] A number of feasibility studies were carried out over the period from 1976 to 1983 and at least 14 large-scale schemes were identified on the six main rivers, indicating a considerable potential of up to 1,000 MW for all sizes of hydropower.[18]

A number of SHP projects are currently being implemented or have been earmarked. The construction of a 1 MW Mein River plant in Suakoko, Bong County in Central Liberia is underway and was expected to be completed in 2015. However, the USAID announced a delay due to issues with the hired contractor.[20,21] It is expected to be community-owned and operated and will serve approximately 2,500 households, 250 commercial entities, a university and a hospital. It is funded by the USAID at a cost of US$5.8 million and the project is to be implemented by Winrock International and United Nations Industrial Development Organization. Additionally, a feasibility study for a 15 kW project along the Wayavah Falls in Lofa County has also been completed by the USAID in cooperation with Winrock International.[15,21]

As already noted, the renewable energy (RE) projects designated under SREP include 18 mini-grids totalling 18.1 MW. These include four 1 MW SHP plants, three 1.5 MW SHP-solar hybrid systems and one 2 MW biomass-SHP hybrid system. The total cost for all 18 mini-grids is estimated at US$178 million. A number of prefeasibility studies have already been carried out. The most advanced, funded by Norway, is a study of the 1.5 MW Kaiha II project on the Kaiha River in the Lofa County. The power plant will be part of the mini-hybrid grid with combination of hydropower, solar PV and diesel generation and will serve Foya-Kolahun-Voinjama area.[11,22] In September 2018, the construction of the road leading to the hydropower plant construction site was commenced.[23] Additionally, according to the RREA, the six most interesting suitable sites for subsequent review and implementation under the SREP are Zeliba (Lofa), Lofa (Cape Mount), Ya Creek (Nimba), MR5 (between Cape Mount & Lofa), FR1 and Farmington (both in Margibi & Bassa).[10,11] As of December 2017, detailed feasibility studies were conducted for three hydropower sites: Gbedin Fall, Ya Creek and River Gee. The Gbedin Fall site was selected for the development of a 9.34 MW plant that would generate 56.5 GWh annually.[4]

Currently, as has been the case for most of the post-war electricity expansion programmes in Monrovia, most of the above-mentioned SREP SHP and other RE projects are funded through grants and low-cost/low-risk financing via credit lines from international, multilateral and bilateral development organizations and Governments including the World Bank, the African Development Bank, USAID, the Government of Norway as well as the Liberian Government.

Renewable energy policy

Liberia does not have a validated and legislated RE policy document. However, the NEP was developed and approved by the Cabinet in 2009. The NEP, in line with the international community, states the long-term strategy to make Liberia a carbon neutral country in energy production and transportation by 2050.[24]

According to the NEP, it is the policy of the Government to facilitate and accelerate the economic transformation of rural Liberia by establishing a semi-autonomous agency. The agency should be dedicated to the commercial development and supply of modern energy services to rural areas, with an emphasis on locally available renewable resources. In response to the NEP, the RREA was established by an Executive Order in 2010 with legislation, including the establishment of the Rural Energy Fund (REFUND), passed and enacted into law in July 2015. According to the NEP, the REFUND is to "provide for the coordinated and sustainable financing of projects and programmes for the delivery of modern energy services for rural development. Once the REFUND has been established it shall become the channel through which all domestic and international financial resources intended for rural energy delivery in Liberia shall be managed."[11,24] The RREA facilitates the funding of rural energy projects, including managing the REFUND that provides low interest loans, loan guarantees and grants as targeted subsidies to ensure access by the poor.[25]

Liberia is a member of ECOWAS and a signatory to the white paper for a regional policy on increasing access to energy services for rural and peri-urban populations, the Energy Protocol that outlines principles for cross-border energy trade and investment and the West African Power Pool (WAPP) to address the issue of power supply deficiency within West Africa. Additionally, Liberia is a signatory to the United Nations Framework Convention on Climate Change and its Kyoto protocol. Lastly, it has also joined the United Nations Sustainable Energy for All Initiative.

In 2015, Liberia adopted the Electricity Law, which established the legal basis for public and private electricity service providers to offer commercial electricity service in Liberia, using grid expansion and offering off-grid service to rural and remote communities. Accroding to the law, licences for operation are to be issued by an independent regulator, the Liberia Electricity Regulatory Commission (LERC), which is also in charge of approving tariff setting methodologies.[26]

Legislation on small hydropower

Apart from the NEP's prioritization and enhancement of the use of RE resources, including hydropower, there is no specific Government policy on SHP.

Barriers to small hydropower development

In spite of all of the above, the main challenge to the SHP sector remains the inadequacy of legal and regulatory frameworks in RE which is crucial to developing the sub-sector and stimulating private investments. Other barriers include:

- Insufficient data on SHP resources and potential;
- Changes in land use patterns that may lead to changes in stream flow patterns in some locations;
- Limited legal and regulatory framework in the energy sector;
- Grid unavailability in rural areas;
- Limited human capacity or expertise in hydropower projects design, development and operation;
- Limited access to capital and financing.[11]

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1.5.8 Mali

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Key facts

Population	18,541,980[1]
Area	1,240,192 km[2]
Climate	Mali lies in an intertropical zone and experiences hot and dry temperatures throughout most of the year. However, the country can be divided into three climatic zones – the desert zone, the Sahel zone and the Sudanic zone. The desert zone is encompassed by the Sahara, which has high temperatures of 47 °C to 60 °C during the day and low temperatures of 4 °C to 5 °C during the night. The Sahel zone, which borders the Sahara, has temperatures averaging from 23 °C to 36 °C and the Sudanic zone has average temperatures of 24 °C to 30 °C.[2]
Topography	The landscape is mostly flat, with rolling northern plains covered by sand and plateaus in the south. When the plateaus descend westwards to the river valley, they turn into abrupt cliffs that reach an elevation of 1,000 metres at Bandiagara.[2]
Rain pattern	The climate allows for a long dry season, lasting from November to June, and a rainy season from June to October. Rainfall ranges annually due to inconsistent climate change. In the Sudanic zone, rainfall can vary from 510 mm to 1,400 mm, while in the Sahel zone, it can vary from 200 mm to 510 mm.[2]
Hydrology	There are two main rivers that cut through Mali, the Niger and the Senegal Rivers. The Senegal River and its tributaries flow in a north-west direction towards the Atlantic Ocean, cutting through Mali for 670 km. The Niger River flows in a north-east direction, across the Mandingue Plateau, until its course is interrupted by waterfalls and a dam at Sotuba. The river flows through Mali for over 1,600 km.[2]

Electricity sector overview

The total installed electricity generating capacity of Mali in 2016 was 672.2 MW, of which thermal power accounted for 53 per cent and hydropower for 47 per cent (Figure 1).[3] This total capacity includes the interconnected grid, isolated grids, the shared power plants of the Organization for the Development of the Senegal River (OMVS) and independent power producers. Most of the hydropower generation is attributed to the 200 MW Manantali Dam, of which Mali owns 104 MW, the 63 MW Félou Dam, of which Mali owns 27 MW, and the Selingue Dam, which has a capacity of 46 MW. However, there are smaller hydropower plants that also contribute to electricity generation.[3] In addition to the capacity from power plants located on its territory, Mali also receives a guaranteed import of 50 MW from Côte d'Ivoire via an interconnection (Table 1).[3] In 2016, total electricity generation was at 1,905 GWh, with hydropower generation at 1,102 GWh.[4]

In Mali, electricity is supplied by Energie du Mali SA (EDM-SA). The regulation and the supply of the electricity and water sector is assured in the urban centres by EDM-SA, while 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).[5,6] Service provision by EDM-SA is carried out in a steady fashion, with common tariffs for all the clients, whereas service provision by AMADER is limited daily, depending on the number of hours agreed upon with the customers. The number of hours varies from one location to another. This approach to providing electricity in rural areas has its advantages but also has some drawbacks for rural consumers, in particular, higher tariffs than the ones applied by EDM.

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

Source: EDM-SA[2]

The EDM-SA operates the Interconnected Network (RI), which supplies the capital city Bamako as well as 31 other cities in the country. The network is primarily composed of a 150 kV line connecting Bamako with the cities of Fana and Segou and originating at the hydropower plant in Selingue, a 63 kV line connecting the cities of Segou and Niono as well as a 225 kV line connecting the cities of Kayes and Kita with

* *WSHPDR 2016* updated by ICSHP

an origin at the hydropower plant of Mantali. Another 225 kV line starting at Ferkessedougou supplies electricity from the interconnection of Mali to Côte d'Ivoire. In addition to the RI, EDM-SA manages 28 centres which are based on isolated production using diesel generators and autonomous distribution networks, as well as two centers that are part of the Ivorian network connected at medium voltage.[3] The total length of transmission and distribution lines in Mali in 2016 was 1,477 km and 7,888 km, respectively.[4]

Table 1.
Electricty capacity of Mali (MW)

Operator	*Location(s)*	*Type*	*Installed capacity (MW)*
EDM owned and operated	Sélingué	Hydropower	47.0
	Sotuba	Hydropower	5.7
	Darsalam	Thermal	36.6
	Balingué	Thermal	24.3
	IDB (Balingué)	Thermal	71.6
SOGEM shared under OMVS	Manantali	Hydropower	200.0 (104.0 owned by Mali)
	Félou	Hydropower	63.0 (27.0 owned by Mali)
SOPAM IPP	SOPAM	Thermal	56.0
Aggreko	Darsalam, Kati and Balingué	Thermal	78.0
SES	Sikasso and Koutiala	Thermal	20.0
Côte d'Ivoire	Guaranteed capacity	-	50.0
EDM-SA Isolated Grids	-	Thermal	70.0
Total	-		**722.2**

Source: EDM-SA[3]

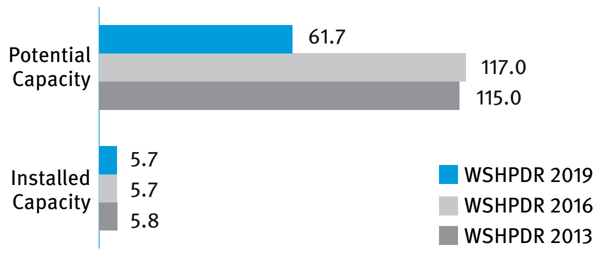
As of 2016, the overall national electrification rate of Mali stood at 35 per cent, with 84 per cent in urban areas but less than 2 per cent in rural areas.[7] However, the Government plans to increase its focus on rural areas and has set a target of 61 per cent electrification by 2033. It is particularly advocating for the development of isolated grids to meet this target.[8] The electricity tariff averages 0.16 US$/kWh, which is below the average cost of electricity service.[9]

Small hydropower sector overview

The definition of small hydropower (SHP) in Mali is from 1 MW to 30 MW. The country has an undeveloped SHP potential of 56 MW, while the current installed capacity stands at 5.7 MW, which comes from the only SHP plant located in Sotuba and generating approximately 36 GWh annually.[3,10] Compared to the *World Small Hydropower Development Report* (*WSHPDR*) *2016*, installed capacity remained unchanged, whereas potential decreased by 47 per cent due to access to new data (Figure 2).

A study carried out by Pöyry Energy GmbH under the ECOWAS Small-Scale Hydropower Programme identified that the total theoretical hydropower potential of Mali is 2,187 MW, of which 1,143 MW is considered attractive for development. Almost all of this potential (1,086 MW) is classified as medium- or large-scale (above 30 MW), while pico/micro/mini-hydropower potential (up to 1 MW) is estimated at 6 MW and small hydropower potential (1 MW to 30 MW) at 50 MW. No undeveloped hydropower potential up to 30 MW has been identified on the Niger River, although the country's only small hydropower plant Sotuba is located on it. Some small hydropower potential of 9.1 MW has been found on the Badinko River, in the Reserve du Badinko. A further 7.6 MW of small-scale and 0.2 MW of pico/micro/mini-hydropower potential has been identified on the Balin Ko River. A significant share of SHP potential is concentrated in the south-western corner of the country by the border with Guinea, namely, on the Faleme River and its tributary – 3 MW of pico/micro/mini-hydropower potential and 19 MW of SHP potential.[10]

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



Source: EDM-SA,[3] *WSHPDR 2016*,[6] ECREE,[10] *WSHPDR 2013*[11]

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

Due to climate change, which might have a considerable impact on future water resources and, therefore, hydropower generation, the Government of Mali intends to decrease the dependency on hydropower. Nevertheless, with the support of the Scale-up Renewable Energy Programme (SREP), four micro- and two mini-hydropower plants are being developed, for an additional capacity of 14.6 MW.[8] Despite the Government's reservations about hydropower dependency, it issued the National Energy Policy Letter in 2009 that lists projects to be completed over the period 2009-2020. These projects include 133 MW of new large hydropower capacity and 100 MW of thermal capacity. Additionally, the African Development Bank (AfDB) has a few other micro- and mini-hydropower projects under construction co-financed by SREP. These will contribute to an overall capacity of 21.6 MW upon completion and include the sites of Djenné and Talo on the existing dams on the Bani River (8.9 MW combined).[8,12]

Renewable energy policy

The Government, in the development of its energy policies, has chosen to support renewable energy (RE) for two crucial reasons: the availability of RE sources and the high price of the country's oil bill. For instance, Mali has a high number of sunlight hours per day (from 5.6 to 7.0 kWh/m^2/day). The targets for RE were set in the National Energy Policy in 2006 and complimented by the Energy Policy Letter of 2009-2012.[6,13]

The Government has also chosen to engage in several energy projects with international funding institutions such as the World Bank and the Climate Investment Funds (CFI). With the World Bank, between 2009 and 2018 the Government carried out the Mali Energy Support Project. The project's aims included 1) transmission and distribution reinforcement and extension; 2) improvement of energy efficiency and demand-side management through efficient lighting; 3) capacity and institutional strengthening.[14] Together with Scatec Solar and Africa Power, the World Bank is also sponsoring the construction of a 33 MW solar photovoltaics power plant in Segou, approximately 240 km north-east of Bamako.[15]

The regulatory environment in Mali is relatively favourable for energy investments. In particular, Mali has the core documents and policies in place that govern the energy sector, the sector is open to private operators with an important track record in rural energy access expansion over the last decade by decentralized energy services companies operating in public-private partnership with AMADER, the national electricity grid is open to neighbouring countries (Senegal, Mauritania, Côte d'Ivoire, Ghana and Burkina Faso) and there is the political will to develop the sector.[6]

Important progress has been made in the separation of the water and electricity subsectors and the reform of the EDM-SA. The opening of the electricity subsector to competition has contributed to increasing the effectiveness of the energy sector as a whole, speeding up the withdrawal of the public sector from operation and expanding service coverage.[6]

The Government recognizes the value added by public-private partnerships for the scaling up of RE, in accordance with the principles of competition and performance-based rights. A framework for public-private partnership was set up in the form of BOOT concession contracts. A decree on the suspension of the value added tax, levies and duties on imported energy equipment is in place.[6]

Barriers to small hydropower development

The barriers for the development of SHP plants in Mali as well as for the development of other renewable energies include:

- Incomplete legislative framework such as shortcomings in the investment code;
- A lack of a preferential fiscal and regulatory framework for RE;
- Investors in the energy sector cannot benefit from the tax-free zone, nor do they have guarantees during site acquisitions;
- An uncompetitive business environment, which makes the sector not attractive enough for investors and private operators;
- Limited coordination among relevant institutions;
- Limited financial resources, which hinders RE access for the poor;
- Difficult return of investment due to an increase in investment costs and the need for an affordable price of kWh for poor households;
- International private investors consider the energy sector of Mali risky.[6,16]

Note: The author, Sinalou Diawiara, worked at the Ministry of Energy and Water of Mali and is now retired.

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1.5.9

Mauritania

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Key facts

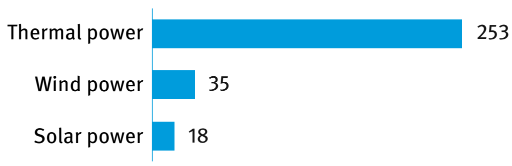
Population	4,420,184[1]
Area	199,900 km[2]
Climate	Influenced by hot and dry winds blowing from the north-east and east, the climate is predominantly arid, whereas precipitation during the rainy season is brought by rain-bearing south-westerly winds. The climate is hot with daytime temperatures in the summer months exceeding 40 °C, while temperatures in the coldest months average 20 to 25 °C.[2]
Topography	The country is predominantly flat. The coastal plains lie at elevations below 25 metres, while the plains of the interior lie at 180 to 230 metres above sea level. The flat topography is interrupted by cliffs reaching up to 275 metres and inselbergs, the highest of which is Mount Ijill at 915 metres above sea level.[2]
Rain pattern	The duration of the rainy season and total annual precipitation vary from south to north. The town of Sélibaby in the far south receives some 635 mm of rain between June and October, Kiffa located further north receives 355 mm between mid-June and mid-October, Tadjikdja in central Mauritania receives 180 mm between July and September, Atar also receives 180 mm between mid-July and September, and Nouadhibou in the north-west receives 25 to 50 mm between September and November. Average annual precipitation across the country is below 140 mm. Rain usually falls in the form of stormy showers.[2,3]
Hydrology	The major river is the Senegal River, which forms the border between Mauritania and Senegal. Its tributaries running southwards are located in the south-west of the country. Due to very scarce precipitation, in the north and west there is almost no runoff.[3]

Electricity sector overview

The main source of electricity generation in Mauritania is thermal power (Figure 1). In 2016, the installed capacity of the electricity system of Mauritania was 306 MW and consisted of the thermal power plants of the Electricity Company of Mauritania (*Société Mauritanienne d'Electricité*, SOMELEC), two solar power projects in Nouakchott and Zoueratt (15 MW and 3 MW), a 4.4 MW and a 30 MW wind power farms in Nouadhibou and Nouakchott and a 22 MW heavy-fuel oil power plant of the National Industrial and Mining Company (*Société Nationale Industrielle et Minière*, SNIM) in Nouadhibou.[4,5] Additionally, there are numerous small-scale hybrid and solar power plants, however, no data on their installed capacity is available. Most of the currently available installed capacity was introduced after 2009, when the capacity stood at 74 MW, thus indicating an almost five-fold increase in less than a decade.[6] In addition to the generating capacities located on the territory of Mauritania, the country also owns shares of the Manantali (18 MW) and Félou (30 MW) hydropower plants, which are located in Mali. In this report, based on the geographical principle, these hdyropower plants are attributed to Mali.

In 2016, power plants of Mauritania generated a total of 900 GWh, which was almost 3 per cent higher than in 2015. Thermal power accounted for almost 60 per cent, hydropower for 25 per cent, wind power for 13 per cent and solar power for 2 per cent (Figure 2). Approximately 94 per cent of generated electricity was fed into the national grid, while the rest was either exported or used for the purposes of auto-consumption.[4]

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

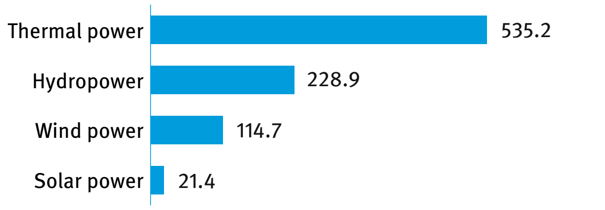


Source: SOMELEC,[4] IRENA[5]

Note: Excluding small-scale hybrid and solar power plants.

All of the currently available hydropower capacity of Mauritania has been developed as part of projects of the Senegal River Basin Development Organization (OMVS). Both the Manantali and the Félou hydropower plants are located in Mali. The Manantali hydropower plant commissioned in 2002 has a capacity of 200 MW, of which Mauritania receives 15 per cent, while Mali and Senegal receive 52 and 33 per cent, respectively. The Félou hydropower plant was commissioned in 2013 and has a capacity of 60 MW, of which Mauritania receives 30 per cent and Mali and Senegal 45 and 25 per cent, respectively.[7] The electricity generated by these plants serves the major cities of Mauritania located on the Senegal River, including Rosso, Kaédi, Sélibaby, Boghé, Gouray and Diaguili.[4]

Figure 2.
Annual electricity generation in Mauritania (GWh)



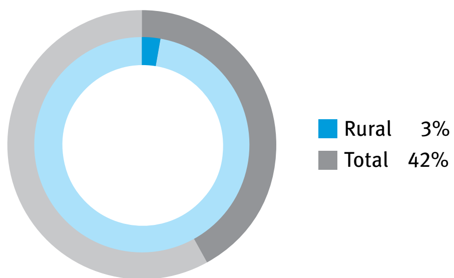
Source: SOMELEC[4]

Note: An estimate based on percentage shares.

Note: Hydropower generation is from the shares of Mauritania in the Manantali and Félou hydropower plants located in Mali.

One major challenge for the country's energy sector is posed by the high share of thermal power in the energy mix, thus, making it dependent on fluctuations in fossil fuels prices. Another challenge is the insufficient coverage of the electricity network. In 2016, less than 42 per cent of the population had access to electricity, with 81 per cent in urban areas and only 3 per cent in rural areas (Figure 3).[8] Taking these challenges into account, the strategic priorities for the Government in relation to the development of the electricity sector are to: 1) increase electricity generation using local resources, in particular hydropower and natural gas; 2) develop the transmission network as well as interconnections with neighbouring countries; 3) increase the share of renewable energy sources in the energy mix; and 4) Introduce decentralized solutions in isolated areas. By 2025, the country's total installed capacity is projected to reach 1,400 MW.[9]

Figure 3.
Electrification rate by source in Mauritania (%)



Source: World Bank[8]

The major projects planned to be introduced by 2030 include a 180 MW heavy fuel oil/gas power plant, a 120 MW combined cycle power plant, hybrid solar/thermal power plants in Nema and Adel Bagrou, a 100 MW wind power plant in Boulanouar, and the Gouina hydropower plant, which will be located in Mali as well and of which Mauritania will receive 35 MW.[5,10,11]

The electricity sector of Mauritania is regulated by the Department of Electricity and Energy Management (DEME) of the Ministry of Petroleum, Energy and Mines (Le Ministère du Pétrole, de l'Energie et des 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 (Agence de Développement de l'Electrification Rurale, ADER). The Multisector Regulatory Authority (Autorité de Régulation Multisectorielle, ARM) created in 2001 is supposed to regulate activities within such sectors as water, electricity, telecommunications and post, however, presently, within the electricity sector it regulates only the service providers, while SOMELEC remains out of its scope of activities. The Agency for the Promotion of Universal Access to Basic Services (Agence de Promotion de l'Accès Universel aux Services de base, APAUS) is in charge of electrification and electricity infrastructure maintenance in certain villages of the country. SOMELEC was created in 2001 as part of the policy on electricity market liberalization. It is in charge of generation, transmission, distribution and sale of electricity in urban and suburban areas of the country. It is also responsible for the management of isolated power grids of Moughataas and the operation of solar and wind power plants connected to the grid. The mining industry also has some generating capacity and has been involved in the electrification of the villages where its production is located.[12]

Electricity tariffs as set by SOMELET are 3.07 MRO/kWh (0.08 US$/kWh) and 5.90 MRO/kWh (0.15 US$/kWh) for residential consumers depending on the subscription plan. For business and industrial consumers of low-voltage electricity the tariff is 59.03 EM/kWh (0.15 US$/kWh). These tariffs have been valid since 9 August 2016 over the entire territory of the country.[14]

Small hydropower sector overview

As of 2018, there were no small hydropower plants installed in Mauritania. All existing hydropower plants are large-scale and have been developed through the Senegal River Basin Development Organization (OMVS), hence, are shared among the participating countries. Thus, there is currently no installed small hydropower capacity in Mauritania, while the potential remains unknown (Figure 4).

Figure 4.
Small hydropower capacities in Mauritania (MW)

Potential Capacity	N/A
Installed Capacity	0

Source: SOMELEC,[4] IRENA[5]

Note: Mauritania is a new country introduced in the *WSHPDR 2019*

Mauritania possesses significant hydropower resources, which are predominantly linked to the Senegal River.

However, the development of the Senegal River potential is carried out within the framework of OMVS. Cooperation among the member countries ensures the rational exploitation of the resources of the river for the purposes of agriculture, hydropower generation and navigation. The location of each project is selected in line with the objective of finding the best solution for all the countries, and as of the moment of writing of this report no projects were foreseen for development within the territory of Mauritania. The combined capacity of developed and planned projects under OMVS is 690 MW, of which Mauritania has received 217 MW. Besides the already operating plants, two large-scale hydropower plants, in Gouina and Gourbassi, are planned to be completed by 2020 on the territory of Mali. Two other planned projects are Koukoutamba (294 MW) and Boureya (114 MW), both of which are to be developed in Guinea.[14] In addition, Mauritania is expected to have some limited small hydropower potential in the south, which could be exploited to provide electricity to smaller communities. This potential, however, still remains to be studied.[5]

Renewable energy policy

In addition to hydropower resources, Mauritania also possesses a significant potential for the development of solar and wind power. The wind power potential is particularly high around coastal areas with wind speeds reaching 7.5 m/sec in Nouakchott and 8.9 m/sec in Nouadhibou. Solar power potential is estimated at some 2,000 - 2,300 kWh/m^2/year, with the lowest radiation measurements being comparable to the highest solar resources in southern Europe.[5]

The country still lacks a comprehensive renewable energy policy that would reflect a long-term vision for the sector, and the development of renewable energy has taken place on an ad hoc basis, resulting in a project-led renewable energy policy. In 2014, with the support of the United Nations Development Programme (UNDP) and the International Renewable Energy Agency (IRENA), a strategy for the promotion of renewable energy was developed, with a particular focus being made on solar and wind power.[15] Pursuing the expansion of the electricity system, the Government foresees that the total installed capacity of the country will reach 752 MW by 2030, of which 280 MW will come from heavy fuel oil and mixed power, 217 MW from hydropower, 180 MW from natural gas and 75 MW from solar and wind power combined, with renewable energy source thus accounting for a total of 39 per cent.[5] Small-scale renewable energy projects are promoted as a solution for rural electrification in communities of 500 to 1,500 inhabitants, while large-scale renewable energy projects connected to the grid are to balance the country's energy mix and support the national programme of ensuring energy efficiency and rational energy use.[16]

At the same time, the national renewable energy strategy is influenced by regional cooperation initiatives Mauritania participates in. Thus, as part of the Arab Maghreb Union (AMU), Mauritania follows the Maghreb Charter on Environmental Protection and Sustainable Development and its renewable energy strategy. Also, Mauritania is an observer in the Economic Community of West African States (ECOWAS), which in 2012 adopted a regional renewable energy policy including a plan to increase the share of renewable energy sources in order to support the development of the West African Power Pool (WAPP) and to contribute to improved energy access. Finally, through SOMELEC, Mauritania participates in the Maghreb Committee for Electricity (COMELEC), with a planned interconnection to Morocco based on the high wind power potential of the Nouadhibou region.[5]

The regulatory framework of the electricity sector is based on the Regulation Act (2001), which regulates the activities related to electricity, water, telecommunications and postal services, and the Electricity Code (2001), which regulates the activities of electricity generation, transmission, distribution and resale.

Barriers to small hydropower development

The key barriers to small hydropower development in Mauritania include:

- Lack of hydrological data;
- Lack of a comprehensive legal and regulatory framework;
- Lack of incentives to stimulate renewable energy investment;
- Lack of financing and funding mechanisms; and
- Limited local capacity to develop and operate small hydropower projects.[5]

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1.5.10 Niger

Rabiou Hassane Yari, Former Ministry of Mining and Energy of the Republic of Niger

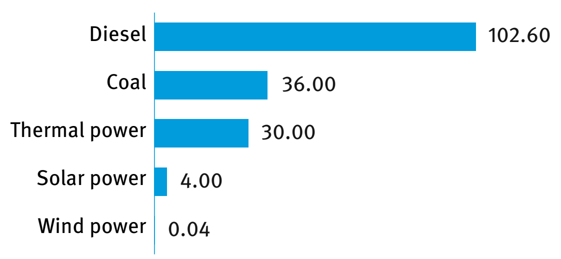
Key facts

Population	21,466,863 [1]
Area	1,266,700 km[2]
Climate	Located in one of the hottest regions of the world, Niger has a typically hot and very dry weather. During the hot season, from North to South, medium temperatures are very high in between 40 °C and 46 °C with some peaks at 50 °C, especially in the far North that is a desert.[3]
Topography	Niger is a large peneplain, with a medium height of 474 metres. The northern area is covered by the Sahara Desert, with some hills and then flat to rolling plains are found in south. The three big areas are southern Niger, Aïr, and Ténéré. The highest point is in the Aïr area on Mount Bagzane at 2,022 metres.[2]
Rain pattern	The rainy season in Niger is short and goes from June to September. The country can be divided from North to South into four areas: the Sahara area in the North (65 per cent of the territory) that receives 100 mm of rain precipitation per year; the Sahel-Saharaian area receives in between 100 and 300 mm of rain precipitation per year; the Sahel-Soudanese area that receives about 300 and 600 mm; and the Soudanese area that receives 600 mm per year. Evaporation is estimated in between 1,700 mm and 2,100 mm per year.[4]
Hydrology	The hydrology network is poor because of the dryness that affects the majority of the country. The main rivers are: the Niger, Africa's third biggest river, 4,200 km in length of which 500 km run through Niger; the Tapoa, Mékrou, Sirba, Dargol, Gorouol, Goroubi, Diamangou are the main rivers that flow into Niger. Lakes, rivers and ponds include Lake Tchad, Komadougou Yobé, and the ponds of Madarounfa, Tabalak and Guidimouni. There are important underground resources with a real but deep groundwater level in the northern area of the country. [5]

Electricity sector overview

In Niger electricity is mainly sourced from thermal power. The country has three main electricity operators. The National Electricity Company (NIGELEC) has a monopoly on transmission and distribution, and the Coal Company Anou Araren (SONICHAR) produces electricity from thermal coal power plant. Since 2011 there is an independent power producer which leases its groups to NIGELEC.[14] In 2015, the national electricity generation was estimated at 499.4 GWh, whereas the imported electricity generation, mainly from Nigeria, amounted to 782 GWh, as NIGELEC cannot cover the population electricity demand.[2]

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



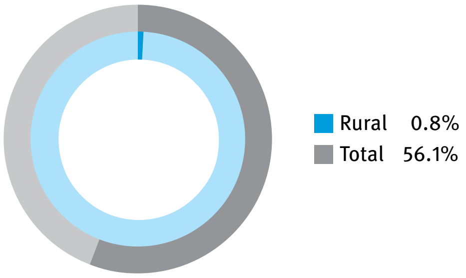
Source: SE4ALL,[6] Gado[14]

Note: Data as of 2015

As of 2015, Niger electricity installed capacity amounts to approximately 172.64 MW. The total diesel thermal power amounts to 168 MW, 102.6 MW produced by NIGELEC, 36 MW produced by the SONICHAR coal thermal plant, and 30 MW produced by independent power plants. Solar power accounts for 4 MW andwind power is estimated at 0.035 MW (Figure 1).[6,14] Diesel thermal and coal power plant continue to play a major role in the production of electricity, despite the fact that all these facilities are old and many have reached age of decommissioning.[15]

In 2010, the estimated rate of access to electricity was 42 per cent in urban areas and about 0.1 per cent in rural areas, where 80 per cent of the population live. For the future, in urban areas the country aims at reaching 71 per cent and 100 per cent by 2020 and 2030 respectively; as for rural areas the targets are set for 15 per cent and 30 per cent for the same years.[6] According to the project for the electrification of rural and urban areas (PEPERN), the plan should target 46,000 households.[7] Over the past 10 years, the access rate to electricity has slightly increased up to 0.76 per cent in rural areas and up to 56 per cent in urban areas, while the national rate is 11.7 per cent (Figure 2). [8]

Figure 2.
Electrification rate in Niger (%)



Source: World Bank,[8] ANPER[16]

Niger's electricity system can be divided into six areas:

- The river area is supplied by the 132 kV interconnection line Birnin Kebbi (Nigeria)-Niamey (Niger). This area represents 65 per cent of the total energy by NIGELEC and 74.5 per cent of imported energy from the Holding Company of Nigeria (PHCN) with 410.5 GWh, with a peak of 85 MW (2010).
- Niger Centre Est (NCE) is comprised of the areas of Zinder, Maradi, and Tahoua is powered by the 132 kV interconnection line of Katsina (Nigeria)-Gazaoua (Niger). This area represents 20 per cent of the total energy by NIGELEC and 23 per cent of PHCN import with 127.2 GWh and a peak of 23 MW (2010).
- The North area covers the areas of Agadez, Arlit, and Tchirozérine. It is powered by the coal thermal power plant of SONICHAR. The energy required by NIGELEC in this area is 34.2 GWh which is 2 per cent of the total energy with a peak of 6 MW (2010).
- The East area covers the region of Diffa and is connected to 33 kV line from Damascus. This area represents 1.2 per cent of the total energy required by NIGELEC and 1.4 per cent of imported energy with 7.5 GWh and a peak of 2 MW (2010).
- The Gaya/Malanville area is powered by an interconnection of 33 kV from Kamba to Nigeria and which imported energy is 6.2 MWh that is 1.1 per cent of the total imported energy;
- The thermal area (isolated centre), powered by diesel groups.[14]

Law No. 2016–05 of 17 May 2016 manages the production, transport, distribution as well as import and export of electricity in the Republic of Niger. The ministry of Energy and Oil's mission is to elaborate and put into effect the national development policies and strategies. The Ministry of Environment is responsible for the application of law texts with regards to the environment sustainability management and against desertification. The National Environment Consilium for Sustainable Development (CNEDD) institution is supervised by the cabinet of the Prime Minister, and its mission is to coordinate the Environmental National Plan for Development (PNEDD), whose programme is sustainable development and energy.

The Niger Electricity Company (NIGELEC,) founded in 1968, is responsible at a national level for the production, transport and distribution of electricity. Within the company there is a cell dedicated to rural electrification. Société Nigérienne de Charbon d'Anou Araren (SONICHAR), created in 1978, is in charge of production and transport of the electricity in the northern region. The Niger Company for Oil Products (SONIDEP) has the monopoly for the supply of oil to other countries.

In Niger, the energy demand is almost entirely covered by traditional energy sources as the 2015 energy balance sheet state where biomass represented 80 per cent of end-user consumption. The demand is largely supported by the use of woods coming from the country's forests, however this endangers the environment for future generations. According to the 2015 energy balance sheet, energy final consumption is estimated at 31,401 GWh (2.7 million toe); that is 0.0017 GWh (0.15 toe/year) per person. This is one of the lowest energy consumptions in the world. The total energy demand is estimated to increase from 916,755 MWh in 2017 to 1,888,477 and 3,940,998 MWh in 2022 and 2027 respectively.

National energy policies aim to guarantee the long-term supply of energy, contribute to social cohesion in order to guarantee the energy access to all at an affordable price, value domestic energy sources, help protect the environment, and strengthen the capacities of the stakeholders in this sector.

In Niger, the electricity tariff structure has to be initially based on the marginal costs of long-term generation, transport and distribution. The goal is to obtain a tariff structure that brings an efficient signal to consumers from an appointed or allocated point of view. From the system's point of view, costs depend on the voltage and on the subscribed power levels. The resulting tariff structure will have to take into account the diversity of the subscribed power (that depends on the hourly usage). In October 2017, Law 2017-796/PRN/ME introduced new energy tariffs valid as of January 2018 until December 2020. The tariff for 0-50 kWh is 59.45 FCFA/kWh (0.16 US$/kWh), while for the low voltage for public lighting is 59.2 FCFA/kWh (0.16 US$/kWh). Medium voltage tariffs vary from 89.19 FCFA/kWh (0.25 US$/kWh) during peak hours to 56.12 FCFA/kWh (0.16 US$/kWh) outside of peak hours.[9] In Niger, the tariffs are valid at national level.

Small hydropower sector overview

Niger does not have a specific definition for small hydropower (SHP). The country adopts the international definition of plants below or equal to 10 MW. At the moment, Niger does not have any SHP installed capacity. Four rivers that flow into Niger river (Mékrou, Tapoa, Gorouol, Sirba) showed interesting possibilities for small hydropower potential of 8 MW (Figure 3).[10] It is estimated that the small hydropower sites in the country, in particular Sirba and Gouroub Dargol, would generate almost 8 GWh per year.[11]

Figure 3.
Small hydropower capacities in Niger (MW)

Source: SE4ALL[10]

Note: Niger is a new country introduced in the *WSHPDR 2019*

These technologies that would be run-of-river systems have the advantage of being less costly and rapid to install. The strategic installation of small hydropower plants would allow the production of electricity near consumer areas, limiting the costly electricity transmissions lines. However, the rivers that flow into the Niger are not full of water all year round because of the dry periods. This would limit the use of hydropower technology.

The total potential hydropower in Niger is estimated at 400 MW. In particular, three potential sites have been identified along the river and their capacity should be 278 MW. The dam of Kandaji with 130 MW (630 GWh), the dams of Gambou and Dyondyonga with respectively 122 MW and 26 MW, Namarigoungou with 90 MW and the small hydropower plant of Malbaza with 5 MW.[10]

Niger has a weak financial capacity to cover the needs of investments and a strong dependence from external financing, and weak exploitation of the financing potential of the private and international sectors, in particular bank and microfinance institutions. The high costs of investment in renewable energy technologies and the general level of poverty and weak financing buying power of the population limit access to electricity. Financing measures are not very attractive for the private sector investors, and the country faces difficulties channelling the sources of international sources for the large-scale development of RE sources.

Renewable energy policy

The renewable energy (RE) sector still lacks its own specific legislation; only the new code on electricity that was introduced in May 2016 (the previous one was from 2003) was drafted to take into account RE sources. The new code, like the previous one, allows the possibility to independently produce electricity, but it also has the obligation to sell surplus to NIGELEC, the State company that is in charge of distribution.[14]

The renewable energy potential in the country is mostly untapped. In 2018, with the support of the World Bank Niger has launched the Project for access to electricity services in Niger (NESAP). The project of about US$ 50 million aims at improving access to electricity thanks to solar power; the amount is divided as a US$ 4.4 million donation and as a US$ 45.55 million loan. NESAP falls within the Renaissance Act 2 of the Republic of Niger aimed at improving rural electrification rate. In order to reach its targets, Niger has received funds from the International Development Association (AID).[11]

According to SE4ALL objectives, by 2020 RE sources should contribute to 30 per cent of the national energy mix. Fifty-seven per cent of the electricity should come from local RE energy. In order to do so, Niger plans to install the Kandadji dam with a capacity of 130 MW, connect about 15 per cent of the rural population to electricity and have about 40 per cent of electricity generation from the renewable energy sources. By 2030, Niger aims at having 150 MW of the solar power connected to the grid and 100 MW off-grid. Besides, solar water heaters should be installed above all food factories, on half of social centres and hotels as well as on 10 per cent of the residential buildings.[6]

As for hydropower, fours sites have been identified to be developed in the future – Kandaji with 130 MW, Gambou with 122 MW, Namarigoungou with 90 MW, and Dyondyonga with 26 MW. As for the solar power there should the following power sites installed – Prodere-2 with 25 MW, Gorou Banda with 22 MW, and Malbaza with 5 MW. Niger has a huge solar power potential thanks to its high hours of sunlight, between 7 and 10 hours per day. This means an estimated energy potential of 5-7 kWh/m^2 per day.[11] In order to meet its RE targets, Niger also plans to bring wind power to 20 MW by 2030, compared to the 0.035 MW available in 2015. In the northern area, wind speed is about 5 m/s while in the south it decreases to 2.5 m/s.[6,12] As for the geothermal power potential, no studies have been carried out.[11] By 2030, Niger aims to have 5 per cent of diesel covered by biodiesel. [6]

Barriers to small hydropower development

The development of hydropower in Niger is limited to the Niger river and its tributaries. Since the 1960s Niger has carried out studies to explore the hydropower potential and feasibility of hydropower projects in the country, however no projects have been built as of yet. The potential for small hydropower project is limitedand only recently there are some projects planned to be constructed. [17] SHP development is also hindered by:

- Climate change, which exacerbates irregular rainfall;
- Resources, such as the weak valorisation of earth and underground resources;
- Financial weaknesses such as weak investment practices.

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1.5.11 Nigeria

Donald Adgidzi, Regional Centre for Small Hydro Power in Africa; Azubike Emechebe, Renewable energy (RE) consultant

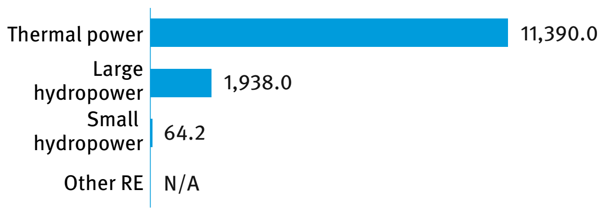
Key facts

Population	193,392,517[1]
Area	923,763 km[2]
Climate	The climate of Nigeria varies throughout different regions in the country. The tropical monsoon climate is found in the southern part of the country while the tropical savanna climate covers most of western to central Nigeria and the Sahel climate is the predominant climate in the northern part of the country.[2] Like other tropical countries, there are only two seasons. The dry season lasts from November to March and the wet season which stretches from April to October. However, in the southern part of the country, the wet season begins earlier, either in February or March. Average monthly temperatures vary from 30 °C in April to 24 °C in January.[3]
Topography	Nigeria has great topographical variety. Although much of the country is dominated by plains generally less than 609.5 metres in altitude, the eastern border with Cameroon is marked by an almost continuous extent of mountains, the Eastern Highlands, which rise to about 2,419 m at the Chappal Waddi, the highest point in Nigeria. In the north, the Jos Plateau rises abruptly from a general height of approximately 609.5 metres in the Hausa Plains to an average level of 1,219 metres, reaching 1,781.6 metres in the Shere Hills.[3]
Rain pattern	Annual rainfall in Nigeria is highest in the southern part of the country and decreases inland towards the north. The lowest levels are found in the northern region of the country. The wettest areas are the coastal regions around the Niger-Delta. The mean annual rainfall received in these areas varies between 2,540 and 4,064 mm. The wet characteristic of the coastal and near coastal areas can be attributed to their closeness to the Atlantic Ocean. Rainfall in the dry season varies from less than 508 mm in the Niger Delta to 0 mm in the north.[3]
Hydrology	Most of Nigeria's rivers flow towards the south, discharging into the Atlantic Ocean. They are largely dominated by the Niger and the Benue Rivers, which converge into each other and form a "Y" shaped confluence at Lokoja before emptying into the Niger Delta, one of the world's largest arcuate fan-shaped river deltas. Nigerian rivers generally show a marked seasonal variation in river stages and discharges. The distribution of average monthly water levels at some gauging stations show that a large proportion of the annual runoff occurs in the rainy season when the monsoon winds bring rain to swell the rivers, occasionally causing floods. During the dry season some of the smaller streams, especially in the northern parts of the country, virtually dry up. The larger rivers are reduced to carrying only a small proportion of their rainy season discharges.[3]

Electricity sector overview

In 2017, electricity generated was approximately 29 TWh, while total installed capacity was approximately 13,400 MW. Most of the power plants are fossil fuel (natural gas) based, contributing to approximately 85 per cent of the installed capacity. Large hydropower, mainly from three power stations, Kainji (760 MW), Jebba (578 MW) and Shiroro (600 MW) was approximately 14.5 per cent, while small hydropower accounted for 0.5 per cent (Figure 1). However, due to the transmission, maintenance, water and gas constraints, less than 4,000 MW of the installed capacity on average was dispatched to consumers between 2015 and 2017.[4] A 10 MW wind farm located in Katsina State is under construction and is expected to be commissioned in 2019.[5]

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



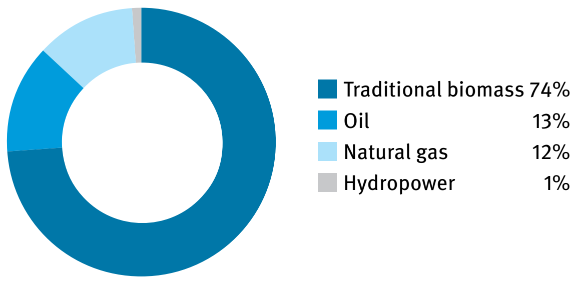
Source: Power Sector Recovery Programme[4]

Nigeria has an electrification rate of 45 per cent (2015 data), with a population of approximately 193 million and an annual growth rate of 2.6 per cent. Approximately 50 per cent of the population lives in rural areas, with 36 per cent having access to electricity.[1,6]

The electricity supply is presently unreliable in the country, with frequent shutdowns, load shedding and grid failures. This has compelled many consumers (both industrial and residential) to rely on diesel or petrol generating sets to meet their electricity needs.

The primary source of energy generation in Nigeria is the burning of traditional biomass and fossil fuel. In 2013, the total primary energy consumption was dominated by traditional biomass and waste (74 per cent), oil (13 per cent), gas (12 per cent) and hydropower (1 per cent) (Figure 2).[7]

Figure 2.
Primary energy consumption by source in Nigeria (%)



Source: U.S. Energy Information Administration[7]

The installed generating capacity of the country increased from approximately 6,000 MW in 2005 to 13,400 MW in 2017, mainly through the National Integrated Power Project (NIPP) initiative. The NIPP, conceived in 2004, is a fast-track government-funded initiative to stabilize Nigeria's electricity supply, while the private-sector led structure of the 2005 Electric Power Sector Reform Act (EPSRA) took effect. The NIPP was designed around gas-fired power stations in the gas-producing states with a cumulative power capacity of 5,222 MW. Despite the increase, the peak capacity generation was still approximately 5,075MW as of 2017.[4,8]

The Government has reformed the electricity industry and enacted several laws and regulations to develop the nation's abundant renewable energy sources. The reform commenced with the preparation of a National Electric Power Policy (NEPP) in 2001, followed by the preparation and passage of the EPSRA into law in March 2005.[9] The NEPP planned a three-stage legal and regulatory reform for the electricity sector comprising of:

- A transition stage characterized by private power generation via Independent Power Producers and Emergency Power Producers, corporate restructuring, unbundling and privatization of the National Electricity Power Authority (NEPA);
- A medium-term stage characterized by the energy trading between generation and distribution companies based on bilateral contracts;
- A long-term competition structure characterized by the optimal operation of the various power generation, transmission and distribution companies.

The EPSRA provides for the vertical and horizontal unbundling of the National Electric Power Authority (NEPA) into separate and competitive entities, the development of competitive electricity markets, the setting out of a legal and regulatory framework for the sector, a framework for rural electrification, framework for the enforcement of consumer rights and obligations and establishment of the performance standards. With the passage of the EPSRA, the NEPA was deregistered and the Power Holding Company of Nigeria (PHCN) was incorporated to manage the unbundling of NEPA into 18 companies – six generating companies (GENCOs), one transmission company (TRANCOs), and 11 distributing companies (DISCOs). Together, these companies constitute the Nigerian Electricity Supply Industry (NESI), which is regulated by the Nigerian Electricity Regulatory Commission (NERC).

This restructuring broke the monopolistic framework of the power sector, allowing private operators to apply for and obtain a license through the NERC to build and operate a power plant with aggregate capacity above 1 MW. It also established the Rural Electrification Agency and an independent Rural Electrification Fund (REF), whose main objective is to fully incorporate renewable energy into the energy mix.

Table 1.
Fixed monthly charges by DISCO 2015-2018

DISCO	*Fixed monthly charge (Nigerian Naira (US$))*			
	2015	*2016*	*2017*	*2018*
Benin	750 (4.50)	900 (5.4)	1 080 (6.48)	1 296 (7.78)
Ibadan	625 (3.75)	750 (4.5)	900 (5.40)	1 080 (6.48)
Ikeja	750 (4.50)	900 (5.4)	1 080 (6.48)	1 296 (7.78)
Eko	750 (4.50)	900 (5.4)	1 080 (6.48)	1 296 (7.78)

Source: NERC[11]

In 2008, the NERC introduced a Multi-Year Tariff Order (MYTO) as part of its effort to provide a viable and robust tariff policy for the NESI, as well as the framework for determining the industry pricing structure. The MYTO provides a 15-year tariff path for the electricity industry with minor reviews bi-annually and major reviews every five years. New tariff classes under the 2012 Tariff Order were published by NERC as a part of the summary of the MYTO-2 Retail Tariffs.[10] A review of this has also been released for 2015. There are three separate Tariff Orders, one for each of the sectors in the NESI namely: GENCOs, TRANCOs and DISCOs/retail. Tables 1 and 2 provide details of residential R2 category tariffs that came into effect on July 1, 2015, for four of the eleven DISCOS. This includes the expected increases for 2016, 2017, and 2018. The charges are in two parts, a fixed monthly charge and an energy charge for the electricity consumption. Energy charges increased significantly from

2014-2015 to reflect the repayments of loans granted to all the DISCOS by the Central Bank of Nigeria.[11]

Table 2.
Energy charges by DISCO 2014-2018

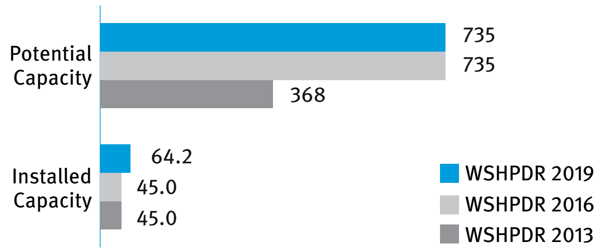
DISCO	*Energy charge (Nigerian Nairi (US$) per kWh)*			
	2015	*2016*	*2017*	*2018*
Benin	18.46 (0.111)	17.02 (0.102)	18.23 (0.109)	15.23 (0.091)
Ibadan	18.00 (0.108)	17.36 (0.104)	19.60 (0.118)	17.93 (0.108)
Ikeja	14.96 (0.090)	14.50 (0.087)	13.88 (0.083)	12.85 (0.077)
Eko	18.75 (0.113)	18.01 (0.108)	19.39 (0.116)	16.42 (0.099)

Source: NERC[11]

Small hydropower sector overview

Small hydropower (SHP) according to the definition in the National Renewable Energy and Energy Efficiency Policy (NREEEP) is defined as 1 to 30 MW in Nigeria (Table 3).[12] As of 2017 the SHP installed capacity was 64.2 MW. Total estimated theoretical SHP potential was 3,500 MW, indicating that only 2 per cent has been developed.[13] Based on data compiled from the planned and studied sites, Nigeria has an economic SHP potential of 735 MW (9 per cent has been developed) (Figure 3).[14]

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



Source: *WSHPDR 2013*,[15] *WSHPDR 2016*,[16] Chidinma E. et al.,[13] Agbonaye A. I.[18]

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

The United Nations Industrial Development Organization (UNIDO) has focused on creating awareness among the relevant stakeholders on the huge SHP potentials available in the country. In November 2002, the Energy Commission of Nigeria (ECN) collaborated with UNIDO and other relevant government parastatals to organize a national stakeholder's forum on RE technologies specifically based on SHP for rural industrialization, with the aim of formulating strategies to provide access to clean and reliable energy sources for Inclusive and Sustainable Industrial Development (ISID). A memorandum of understanding was signed between ECN, UNIDO and the International Center on Small Hydro Power (ICSHP) for further cooperation in harnessing the identified SHP potential.

The ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), in collaboration with UNIDO, has also jointly developed the ECOWAS Small Scale Hydropower Program (2013-2018) for the West Africa Region. Prior to the intervention of UNIDO, SHP development in the country had been minimal. Approximately 64.2 MW of SHP has been developed so far.

Table 3.
Categories of hydropower by installed capacity

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

Source: NREEP[11]

UNIDO's intervention includes the establishment of the following pilot plants – Ezioha Mgbowo (30 kW) in Enugu State, Waya Dam (150 kW) in Bauchi State, and Tunga Dam (400 kW) in Taraba State. The Tunga plant was operational as of 2017. SHP capacity has been developed in various higher institutions and river basins in the country. This has led to the identification of over 200 potential SHP sites, 17 feasibility studies with detailed project reports carried out and the development of three sites that are under construction, including a 1,200 kW capacity SHP project in Benue State with donor support. Although 17 sites have bankable documents, private investors are hesitant to develop them as the initial investment costs are high and obtaining finance is difficult. In the 5th Global Environmental Facility (GEF-5) project cycle, 3.1 MW of the cumulative capacity have been planned for direct implementation and to be replicated by private investors, to an estimated capacity of over 30 MW.[17]

UNIDO has facilitated the transfer of technology in manufacturing micro-hydropower turbines up to a capacity of 125 kW to the National Agency for Science and Engineering Infrastructure (NASENI). Under the same GEF-5 cycle, upscaling of local turbine and control system manufacturing to 300 kW capacity has been planned.

The Renewable Energy Master Plan launched in 2005 aims to increase the contribution of RE to account for 10 per cent of the Nigerian total energy consumption by 2025. The initial targets of the policy based on peak supply from SHP were 40 MW by 2007, 100 MW by 2008, and 400 MW by 2016. These targets assumed that the 200 identified potential SHP sites would be developed. However, achieving these targets has been a difficult task.[14]

The EPSRA allows a person to construct, own or operate an off-grid power plant not exceeding 1 MW in aggregate at a site without a license. This exemption to holding a license favours energy generation through SHP since some of the identified SHP sites fall within the required range. It is also expected to encourage the private sector participation to invest in small, mini and micro hydropower especially for the rural development and off-grid generation.

Renewable energy policy

Nigeria has a renewed focus on electrification using RE sources. It aims to create a conducive environment for the independent power producers to invest in RE based power plants which is in line with the Nigerian Energy Policy, the Nigerian Renewable Electricity Policy, as well as the Renewable Energy Master Plan and Vision 2020, which aims to generate 6,000 MW of electricity through the renewable energy sources by the year 2020.[14] To develop the potential of its RE resources and achieve the Millennium Development Goals and National Economic Empowerment Development Strategy targets, the government has formulated numerous RE related policies including:

- The National Energy Policy, which contains RE, initiated by the Energy Commission of Nigeria and approved by the Federal Government in 2003;
- The Draft Renewable Energy Electricity Policy initiated by the Federal Ministry of Power in 2006;
- The Nigerian Biofuels Policy Incentives initiated by the Nigeria National Petroleum Company and approved by the Federal Executive Council (FEC) in 2007;
- The Vision 2020 document, initiated by National Planning Commission and approved by FEC in 2012;
- National Climate Change Policy initiated by the Federal Ministry of Environment and approved by the FEC in 2011;
- The National Environmental Regulation (2009, 2011) initiated by the National Environmental Standards and Regulations Enforcement Agency;
- The EPSRA of 2005, which liberalized the electricity sector, unbundled the PHCN in preparation for its privatization, and established the NERC as the sector regulator;
- The feed-in-tariff for electricity generated from RE sources initiated by the NERC;
- The Renewable Energy Master Plan (REMP) which aims to increase the contribution of RE to account for 10 per cent of the total energy consumption in Nigeria by 2025.

Financing is crucial to realizing the federal government's policy on RE and funding requirements will be substantial. New investments are needed for the research and development activities. The required type of financing is long term and would involve both foreign and domestic financing resources, though foreign investment capital will provide the greater proportion of the funds needed.

The Government will provide guarantees and financial frameworks aimed at stimulating the expansion of the renewable energy market. Considering the risks involved in financing renewable energy projects, government investments should enhance the rates of return and shorten the payback periods to attract investors.[11]

Table 4.
Renewable energy FITs 2012-2016 by source

Type of power plant	Wholesale contract price (Nigerian Naira (US$) per MWh)				
	2012	2013	2014	2015	2016
Large hydro-power	4,898 (29.39)	5,290 (31.74)	5,715 (34.29)	6,174 (37.04)	6,671 (40.03)
Small hydro-power	23,561 (141.37)	25,433 (152.60)	27,456 (164.74)	29,643 (177.86)	32,006 (192.04)
On-shore wind power	24,543 (147.26)	26,512 (159.07)	28,641 (171.85)	30,943 (185.66)	33,433 (200.60)
Solar power	67,917 (407.50)	73,300 (439.80)	79,116 (474.70)	85,401 (512.41)	92,192 (553.15)
Biomass power	27,426 (164.56)	29,623 (177.74)	32,000 (192.00)	34,572 (207.43)	37,357 (224.14)

Source: NERC[9]

To ensure a stable and attractive pricing policy for RE sources, the NERC has developed FITs for SHP schemes not exceeding 30 MW, as well as all biomass co-generation, solar and wind-based power plants. It is expected that specific tariff regimes formulated by the NERC shall be long term, guarantee buyers under a standard contract and provide reasonable rates of return. NERC will also develop other tariff-related incentives and regulations to support renewable electricity adoption.[11]

Barriers to small hydropower development

The main barriers faced by the SHP sector include:

- Inappropriate policy, institutional and regulatory frameworks to stimulate demand and attract investors. Athough several policies and regulatory frameworks are in place to promote RE based electricity, there is no definite and well-framed pathway to make these policies successful.
- The comparatively high initial investment costs of SHP development.
- Inadequate private sector participation in SHP development. So far, the private sector is only actively involved in the importation and marketing of RE 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 program 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.

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1.5.12 Senegal

Soussou Sambou, Cheikh Anta Diop University of Dakar; and International Center on Small Hydro Power (ICSHP)

Key facts

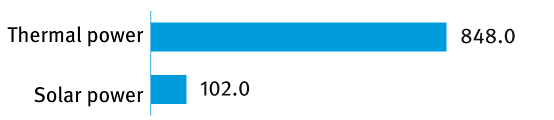
Population	15,850,567[1]
Area	196,722 km[2]
Climate	There are three main climate zones in Senegal – coastal, Sahelian and Sudanic. The coastal zone extends along the Atlantic coast from Saint-Louis to Dakar. It has cool winters with minimum temperatures of 17 °C in January and the maximum temperatures of 27 °C in May. The Sahelian climate zone lies between the Senegal River and the line running from Thiès to Kayes in Mali. This zone has cool winters, with night-time temperatures dropping to 14 °C in January. In May temperatures range between 22 °C and 40 °C. The Sudanic zone lying in the south of the country is characterized by a hot and humid climate.[2]
Topography	Senegal lies in the depression known as the Senegal-Mauritanian Basin and is characterized by a flat terrain. Elevations of more than 100 metres above sea level can only be found on the Cape Verde Peninsula and in the south-east of the country. Senegal can be divided into three geographical areas: the Cape Verde headland in the west, which consists of small plateaus of volcanic origin; the mountain masses in the south-east and east of the country, which include the highest point at 581 metres near Népen Diakha; and a large shallow landmass lying between the western and eastern ends of the country.[2]
Rain pattern	In the coastal zone the rainy season lasts from June until October with a peak in August and an annual rainfall of approximately 500 mm. The Sahelian zone experiences a dry season from November to May, while rainfall between July and October averages some 360 mm. In the Sudanic zone rainfall averages between 740 mm and 990 mm, occurring on approximately 60 days between June and October. Annual rainfall in the Gambian area frequently reaches 1,270 mm.[2]
Hydrology	The main rivers are the Senegal, Gambia and Casamance Rivers, all of which are subjected to a monsoonal climatic regime with dry and rainy seasons. The Senegal River is considered the most important waterway since it passes a long route through the interior of the country. It 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, which supplies Lake Guier. In the south, the estuaries are muddy and salty, occasionally forming saline depressions known as tannes.[2]

Electricity sector overview

The total electricity installed capacity of Senegal as of 2017 was 950 MW, of which thermal power accounted for 89 per cent and solar power for 11 per cent (Figure 1).[3] In May 2018, the President of the Republic, Macky Sall, announced that the country's installed capacity reached 1,200 MW.[4] In addition to the above-stated capacity located on the territory of Senegal, the country also owns 66 MW from the 200 MW Manantali hydropower plant, located at the border of Mali, as well as 15 MW from the 60 MW Félou hydropower plant, shared with Mali and Mauritania.[5] In this report, based on the geographical principle, these hydropower plants are attributed to Mali.

In 2017, the peak demand reached 606 MW and 3,920 GWh of electricity was generated (Figure 2). Of this, 2,140 GWh was from the Société National d'Éléctricité du Senegal (Senelec). Electricity consumption stood at 3,179 GWh from 1,332,075 clients.[3] In 2016, Senegal recorded an electrification rate of 64.5 per cent, with 87.7 per cent in urban areas and 38.3 per cent in rural areas.[6]

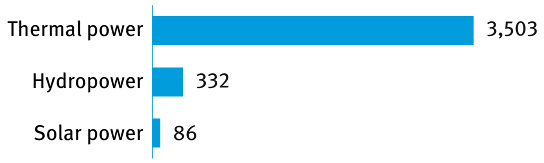
Figure 1.
Installed electricity capacity by source in Senegal (MW)



Source: Senelec[3]

Energy demand in Senegal has been increasing. Frequent electricity outages have caused a slowdown of the economic and manufacturing activities and the closure of many small and medium-sized enterprises. In June 2011, power cuts sparked violent riots in Dakar and other towns. However the situation has been improving significantly since 2015 due to the introduction of new power plants.

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



Source: Senelec[3]

Note: Hydropower generation is from the shares of Senegal in the Manantali and Félou hydropower plants located in Mali

Senegal is shifting from the diesel-based power generation to cheaper energy sources. One of the proposed projects is the 125 MW coal-fired Sendou power plant, which is planned to be launched in 2018. Furthermore, efforts are being made to produce biofuels to run electricity generation units, with a pilot project using sugarcane-based ethanol being planned.

The energy sector of Senegal is overviewed by the Ministry of Petroleum and Energy.[7] Following the institutional reform of 1998, the electricity sector was split into three entities – Senelec which is the national utility, the Agency for Rural Electrification (ASER) and the Electricity Regulatory Board (Commission de Régulation au Secteur de l'Electricité, CRSE). The CRSE was set up to approve concessions and investment plans for the power sector. The ASER is in charge of rural electrification activities. Senelec is a vertically integrated public company responsible for electricity generation, transmission, distribution and retail. Additionally, the company identifies and finances new projects. Electricity generation is open to the private sector, and Senelec signs power purchase contracts with Independent Power producers (IPP).[8]

Electricity tariffs are set by the CRSE. Electricity prices for households, as valid since May 1, 2017, range from 90.47 XOF/kWh (0.16 US$/kWh) to 112.65 /kWh (0.20 US$/kWh) depending on the level of consumption.[9]

Small hydropower sector overview

The definition of small hydropower (SHP) in Senegal is hydropower plants with capacity up to 10 MW. Senegal does not have any small hydropower (SHP) plants on its territory. The potential of SHP has not yet been assessed.

All hydropower capacities available to Senegal have been developed under its cooperation with the neighbouring countries – the Senegal River Basin Development Organization (OMVS) and the Gambia River Basin Development Organization (OMVG). The main hydropower plant, the Manantali plant, is located on the Bafing River, the main tributary of Senegal River in the upper basin, in Mali. It was developed in cooperation with Mali, Mauritania and Guinea within the OMVS framework. The hydropower plant has a capacity of 200 MW, generating approximately 740 GWh per year.[10] In 2015, the OMVG completed the 240 MW Kaleta hydropower plant, located in Guinea. Other planned projects include the 140 MW Gouina Dam, 18 MW Gourbassi Dam, 114 MW Boureya Dam, 294 Koukoutamba Dam, 128 MW Samba Ngalou Dam, and 70 MW Badoumbe Dam.

Renewable energy policy

Senegal has attempted to reform its energy agenda to better promote renewable and sustainable energy. In order to achieve this, the Government passed the Renewable Energy Law, Phase 1 of the Senegalese National Biogas Programme, the 2007-2012 Special Programme for Biofuels, and the Programme for the Promotion of Renewable Energies, Rural Electrification and Sustainable Supply in Domestic Fuel (PERACOD). The Renewable Energy Law provides a legal framework for tax exemptions for the purchase of equipment or materials necessary to develop renewable energy (RE) production for domestic use. The law also created the foundation for a feed-in-tariff (FIT) scheme.[11,12]

Phase 1 of the Senegalese National Biogas Programme initiated a call for the diversification of the country's energy mix, since its energy demand is on the rise and the country is heavily dependent on oil imports. The first phase seeks to install 8,000 biodigestors in three regions of the Peanut Basin (Fatick, Kaolack and Kaffrine), as sources of sustainable energy for cooking and lighting. The biogas waste is also intended to be used for agricultural purposes in the region, thus improving the efficiency of agriculture in the Peanut Basin. The 2007-2012 Special Programme for Biofuels intends to help the country improve its energy independence and achieve biodiesel self-sufficiency. PERACOD aims at increasing rural energy access through the deployment of domestic fuels and RE. The programme is being assisted by the German Development Agency.[11,12]

It is clear that RE is viewed as both important in its own right and also as an enabler for the broader development of the energy sector, rural development and poverty reduction. There are a number of institutions and frameworks dedicated to the further development of RE in Senegal, including the Centre for Studies and Research into Renewable Energy at the University of Dakar. More broadly, agencies such as the ASER, The Association Sénégalaise de Normalisation and the CRSE include RE as a central part of their remit. Cross-institutional cooperation has been facilitated by the establishment of an Inter-ministerial Committee on Renewable Energy (CIER) and the National Committee of Biofuels. Maintaining and extending this cooperation will enable the ongoing success in the implementation of the country's vision for RE. In particular, efforts could be usefully directed at ensuring the participation of the civil society. The domestic commitment to RE is reflected in the role that Senegal has assumed in regional and international forums, including in cross-Sahelian initiatives in design and implementation and under the International Renewable Energy Agency (IRENA) and the ECOWAS Regional Centre for Renewable Energy and Energy Efficiency (ECREEE).[12]

The Senelec Production Plan for 2017-2030, among other goals, foresees the diversification of the energy mix and reduction of electricity services, in particular by increasing the share of renewable energy sources, in particular wind and solar power. Thus, between 2017 and 2020 it is planned to add some 345 MW of RE capacity – 195 MW of solar power and 150 MW of wind power. By 2025, RE is expected to reach a 30 per cent share of electricity generation.[13]

Barriers to small hydropower development

The main barriers to SHP development in Senegal are:
- Flat terrain;
- Inadequate grid availability;
- Deficient infrastructure;
- Poor business environment;
- Lack of local capacity;
- Inadequate tax base and collection;
- Limited comprehensive mapping of RE sources in key areas;
- Limited availability of hydrological data;
- The need for Senegal to adapt the rules of intervention for the regulator in the specific case of small electricity producers;
- The need for Senegal to facilitate grid integration of electricity generated from renewable energy resources;
- The need to identify the conditions for increasing private sector involvement in RE-related manufacturing.[14,15]

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1.5.13 Sierra Leone

Donald Adgidzi, Regional Centre for Small Hydro Power in Africa; Daniel Paco, ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE); and International Center on Small Hydro Power (ICSHP)

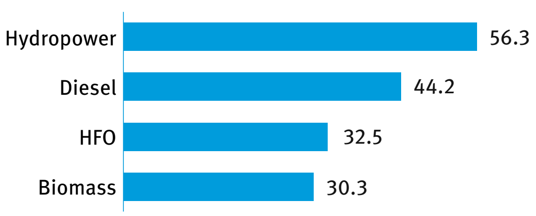
Key facts

Population	7,557,212[1]
Area	71,740 km[2]
Climate	Sierra Leona has a tropical climate with two seasons. 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-west monsoon. Average temperatures vary between 25 °C and 28 °C.[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 km. 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.[2,3]
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: the coast to 80 km inland, with rainfall greater than 3,300 mm per annum; 80 to 190 km inland, with an average annual rainfall of 2,500 to 3,300 mm; and 190 km inland to the border areas, with an average annual rainfall of between 1,900 mm and 2,500 mm.[2,3]
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.[2]

Electricity sector overview

The energy sector in Sierra Leone is highly dependent on the use of imported petroleum (petrol, diesel, kerosene), hydropower and biomass (wood and charcoal). The total installed electricity generation capacity in mid-2016 was 163.2 MW, with 47 per cent coming from diesel and heavy fuel oil (HFO) combined, 34 per cent coming from hydropower and 19 per cent from biomass (Figure 1).[4] The installed capacity is predominantly concentrated in the northern and western regions of the country (Table 1).

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



Source: Turrey & Saffa[4]

Table 1.
Electricity generating capacity by region in Sierra Leone

Region	*Biomass (MW)*	*HFO (MW)*	*Diesel (MW)*	*Hydropower (MW)*	*Total (MW)*
West		26.50	25.00		51.50
North	30.25	6.00	7.18	50.30	93.73
South			10.00		10.00
East			2.00	6.00	8.00
Total	**30.25**	**32.50**	**44.18**	**56.30**	**163.20**

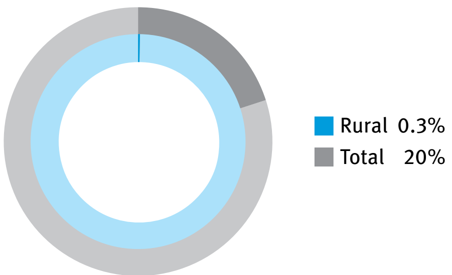
Source: Turrey & Saffa[4]

In 2017, the country's total installed capacity reached 300 MW, indicating a three-fold increase since 2014 when it stood at only 100 MW.[5] Such an increase was achieved due to the introduction of a number of new projects, including a 6 MW thermal power plant in Lungi, a 2.2 MW hydropower plant in Charlotte, a 2 MW hydropower plant in Bankasoka, a 3 kW hydropower plant in Makali and a 7.5 kW hybrid solar/hydropower plant for the River No 2 Community.[5] Among larger-scale projects is a biomass power plant in Makeni with a planned capacity of 32 MW, of which 15 MW was commissioned in 2014.[6] Electricity generation in 2017 stood at 330 GWh.[5]

As the nation is still recovering from its prolonged civil war (1991-2002), the electricity generation, transmission and distribution infrastructure are in need of renovation.[7] The Government, with the support of a number of foreign partners, is currently engaged in a number of projects aiming to improve the transmission and distribution network. These include emergency grid works for a 128 MW generation project in the Western Area, the rehabilitation of the network in Western Area with the support of the Government of Japan, the rehabilitation of the Black Hall Road – Wellington line under the World Bank Energy Access Project, the 525 km West Africa Power Pool (WAPP) network interconnecting Côte D'Ivoire, Liberia, Sierra Leone and Guinea, the electrification of Bumbuna Township, and the reinforcement and expansion of the medium- and low-voltage network in the Western Area under the Islamic Development Bank (IDB).[5]

In 2016, the national electrification rate was 20 per cent (Figure 2). In rural areas, only 0.3 per cent had access to electricity. In urban areas, this increased to 47 per cent.[8] The Government has a target to reach 50 per cent electricity access by 2020, 75 per cent by 2025 and 100 per cent by 2030. Currently, most of the energy needs at the household level are met through the use of traditional sources such as wood and charcoal.[7,9]

Figure 2.
Electrification rate in Sierra Leone (%)



Source: World Bank[8]

The Government has projected a strategic plan in the National Energy Policy to increase electricity generation capacity to 1,000 MW by 2017. Another main objective of the Policy is to develop the energy supply infrastructure countrywide by advancing alternative sources of energy without adversely affecting the five pillars of the 25-year Development Plan: an environment for economic and social development, good governance, improvement of the national security, employment creation and poverty alleviation.[10]

Sierra Leone has a great hydropower potential, which is enough to supply the capital city of Freetown and to export excess electricity to neighbouring countries.[7] Total theoretical potential is estimated at 4,381 MW, of which 3,787 MW is considered attractive for development.[11] Only approximately 1.5 per cent of the hydropower potential in the country has been tapped so far. In terms of generation costs, Yiben I and II, Bekongor III, Kambatibo and Betmai III falls are the most promising plants.[12] The 50 MW Bumbuna I plant came online in 2010.[9]

The authority responsible for the electricity sectors is the Ministry of Energy, which is in charge of policy formulation, planning and coordination and is also responsible for electric power supply, including matters related to renewable energy (hydropower, solar and wind power).[13] The Ministry of Agriculture, Forestry and Food Security is responsible for matters related to biomass, especially fuel wood.[14]

Before 2016, the electricity sector of Sierra Leone was operated by the National Power Authority (NPA) established under an Act of Parliament in 1982. As the country's state-owned electricity provider, NPA was responsible for the generation, transmission, distribution, supply and sale of electricity. However, because of the challenges faced by NPA, the Government repealed the Act of Parliament that empowered NPA as the sole monopolist of electricity supply. Following the National Electricity Law, approved in November 2011, NPA underwent an unbundling into two entities, the Electricity Generation and Transmission Company (EGTC) and the Electricity Distribution and Supply Authority (EDSA), in January 2015. The unbundling is expected to encourage private participation in electricity generation in order to restore power in areas with low electricity access. The Energy and Water Regulatory Commission will oversee the sector, enabling a separation of regulatory and commercial functions. The EDSA will operate as a bulk buyer.[15]

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 develop renewable energy sources and energy action plans of 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 sectors and interconnection among countries to enhance energy security. Currently, Sierra Leone does not import electricity. However by joining the WAPP, the country has the potential to become both an importer and an exporter of electricity and to compensate for seasonal variations in hydropower generation.[16]

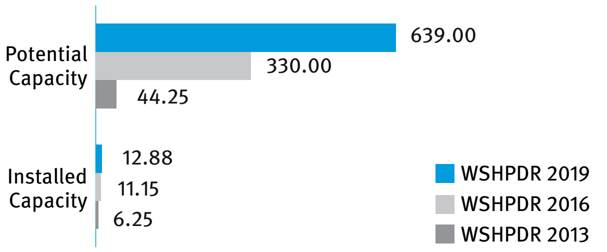
Electricity tariffs in Sierra Leone are however among the highest in Africa. Due to reliance on expensive thermal generation, the electricity sector cannot recover its operating costs and has remained dependent on Government subsidies.[17] In 2018, EDSA proposed an increase in electricity prices, including a 179 per cent increase for the category of consumers using up to 50 kWh of electricity per month – from 560 SLL/kWh (0.067 US$/kWh) to 1,560 SLL/kWh (0.190 US$/kWh).[18] Due to concerns expressed by the public, the tariffs were revised and set at the following levels: 644 SLL/kWh (0.077 US$/kWh) for the 'social band' category consuming up to 50 kWh per month; 1,627 SLL/kWh (0.190 US$/kWh) for residential users consuming above 50 kWh; 1,887 SLL/kWh (0.220 US$/kWh) for commercial consumers;

1,755 SLL/kWh (0.210 US$/kWh) for institutions; 2,017 SLL/kWh (0.240 US$/kWh) for industries; and 2,083 SLL/kWh (0.250 US$/kWh) for welding.[19]

Small hydropower sector overview

The definition of small hydropower (SHP) in Sierra Leone is installed capacity up to 30 MW.[9] As of 2017, the installed capacity of SHP in the country was 12.88 MW, including one decommissioned plant, while the potential capacity is estimated to be 639 MW.[5,11,20] This indicates that approximately 2 per cent has been developed. Between the *World Small Hydropower Development Report* (*WSHPDR*) *2016* and *WSHPDR 2019,* installed capacity has increased by approximately 16 per cent (Figure 3).

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



Source: Ministry of Energy,[5] ECREEE,[11] UNDP,[20] *WSHPDR 2016*,[21] *WSHPDR 2013*[22]

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

The majority of the installed capacity comes from the run-of-river Dodo plant (6 MW) operated by Bo-Kenema Power Services (BKPS).[20] Other operational plants are the 0.25 MW Yele HPP launched before 2010 and the three recently commissioned plants, including the 3 kW Makali HPP completed in 2015 under a grant by the Chinese Government, the 2.2 MW Charlotte HPP completed in 2016 also under a grant by the Chinese Government and the 2 MW Bankasoka HPP located in New Port Loko town and commissioned in 2017 under a project funded by the Chinese Government, the United Nations Industrial Development Organization (UNIDO) and the Government of Sierra Leone.[5,23] The 2.4 MW plant at Guma was decommissioned in 1982.[20]

According to the 2017 ECREEE report, Sierra Leone has 639 MW of theoretical SHP potential, including 140 MW of pico-, mini- and micro-hydropower.[11] The Government has a vision to develop all of its hydropower potential and to install thermal generation to complement the envisaged hydropower plants.[10]

Since 2012, UNIDO has been working on a feasibility study for a 10 MW hydropower project linked to Njala University at the Moyamba district. In 2013 it was announced that the Moyamba hydropower project, which is located at the Singimi Falls on the Gbangba River in Moyamba district, would be developed as a public-private partnership and will supply power to Moyamba, Njala University and Sierra Rutile.[24] UNIDO is financially supporting the Government in this construction estimated at US$ 32 million.[25] In addition, the Small Hydropower Technology Centre was opened at the Fourah Bay College (FCB), affiliated with the University of Sierra Leone. The centre opened after FCB signed a Memorandum of Understanding with UNIDO and Global Environment Facility in 2004.[26]

Renewable energy policy

The Government announced the launch of the National Energy Policy Implementation Strategy in 2010 and set out plans for achieving the renewable energy goals established in the Policy.[16] It foresaw achieving 18 per cent of electricity generated from renewable energy sources by 2015.[9]

Currently, the Government has several objectives regarding development and RE, which are set forth in the National Renewable Energy Action Plan (NREAP) of 2015. Some of the targets include:
- Increasing installed RE capacity, reaching 659 MW by 2020 and 1,229 MW by 2030;
- Increasing access to RE via off-grid solutions including mini-grids;
- Increasing the number of households with solar heating systems;
- Increasing the share of RE in the generation mix to over 25 per cent of total capacity by 2020, in large part due to hydropower.[27]

The Government has drafted a strategy in order to achieve these objectives, which includes the promotion of the public-private partnerships for large RE projects by incorporating the surrounding community in the operation and ownership of the plant, establishment of regulations for grid connections and adjustment of tariffs. To promote private investment in small RE projects, the Government plans to establish power purchase agreements and clear policies for feed-in tariffs (FITs), as well as have tax incentives for importing RE equipment.[27]

In May 2016, the Government adopted the National Renewable Energy Policy (NREP) and the National Energy Efficiency Policy (NEEP), which were launched in 2018. NREP and NEEP outline the status of renewable energy in the country and define objectives and measures for the sector. In particular NREP sets 15 objectives, including direction of public resources for the implementation of renewable energy projects, creation of a Central Energy Fund, introduction of appropriate fiscal incentives, creation of a favourable investment climate, phaseout of fossil fuel subsidies, attraction of foreign investments, development of local renewable energy technologies and encouragement of local Government and community investment in renewable energy projects.[28]

Barriers to small hydropower development

Sierra Leone faces several barriers hindering the development of SHP plants, these barriers can be grouped into:

- Political: Sierra Leone suffered from 11 years of war that caused economic damage and widespread destruction to the infrastructure;
- Financial: There is a lack of financial investment and funds for SHP projects, caused to some extent by the lack of incentives to attract investors;
- Capacity building: A network of gauging stations for regular water level and runoff measurements and hydrological data collection is available at hydrological stations but hydrology departments at universities and training institutes are still missing. Lack of local experts, trained specialists for strategic planning, operation and maintenance in this field;
- Technical: There is a lack of local production of equipment, turbines and spare parts;
- Institutional: Absence of an adequate institutional framework and a lack of local consultancy capacity.[7,29]

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1.5.14 Togo

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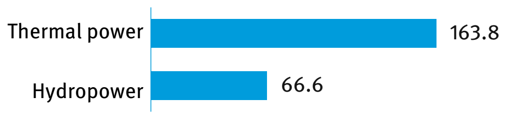
Key facts

Population	7,797,694[1]
Area	56,785 km[2]
Climate	The climate is tropical, hot and humid in the south and semi-arid in the north. Average temperatures vary from a minimum of 13 °C to 23 °C to a maximum of 30 °C to 34 °C.[2]
Topography	The terrain is represented by a gently rolling savannah in the north, central hills, a southern plateau, a low coastal plain with extensive lagoons and marshes. The average elevation of the country is 700 metres above sea level, with the highest point in the Togo Mountains at the peak of Mount Agou (986 metres).[2]
Rain pattern	In the northern part of the country, there is one wet season (May to November) and one dry season (December to March) when the harmattan wind blows north-easterly. The south has two wet seasons, one from March to July and another shorter wet season from September to November. The northern and central regions receive 200-300 mm of rain per month in the peak months of the wet season (July to September). The average annual rainfall in coastal areas is 950 mm.[2]
Hydrology	Lake Togo is the largest of the inland lagoons lining the coast and is also the country's largest natural body of inland water. The Mono River flows north to south, traversing more than half of the length of Togo before flowing into the Gulf of Guinea. Together with its tributaries, it drains most of the south of the central mountain chain. The river is torrential and has an annual average intake of 99.6 m³/s, but only 4.8 m³/s in the dry season (January to May). The Oti River drains into the Volta River, which flows to the north-west.[3]

Electricity sector overview

In 2016, Togo generated approximately 1.1 GWh of electricity.[4] The country's installed capacity in 2016 was approximately 230 MW, of which thermal power plants accounted for 71 per cent and hydropower plants for the remaining 29 per cent (Figure 1).[4] This capacity included the power plants operated by the Electricity Community of Benin (Communauté Électrique du Bénin, CEB), of which 85 MW is installed in Togo (one 20 MW gas turbine in Lomé and two 32.5 MW hydropower turbines in Nangbeto); 45.4 MW of the capacity operated by the Electricity Energy Company of Togo (Compagnie Energie Electrique du Togo, CEET), including a 1.6 MW hydropower plant in Kpimé; and 100 MW (LFO, HFO, gas) of capacity exploited by the independent power producer Contour Global Togo S.A. (Table 1).[4]

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



Source: ARSE (Autorité de Réglementation du Secteur de l'Électricité)[4]

In 2016, four out of five regions of the country (Maritime, Plateaux, Centrale and Kara) were covered by the electric network extending from Lomé in the south to Kantè in the north. The fifth region, Savanes, is served by the network connected to the CEB.[4] A number of remote locations not connected to the grid are served by isolated diesel systems installed under the Government programme of rural electrification. In 2016, there were 19 of such locations. Their total installed capacity was 5.5 MW, of which 4.7 MW was available capacity. The installed capacity of individual plants ranges from 32 kW to 800 kW.[4]

Togo has two operational hydropower plants, with at least one large and eight small plants planned. The 65 MW Nangbeto hydropower plant is located on the border with Benin, and through the energy agreement for the two countries, the generation and capacity is split between them.[5] In March 2016, the works started for the construction of the 147 MW Adjarala hydropower plant on the Mono River and are expected to be completed within four years.[6]

While Togo has vast reserves of renewable energy (RE) sources, they mainly remain untapped. This, combined with an increasing electricity demand, requires imports from the neighbouring Ghana, Côte d'Ivoire and Nigeria to meet the demand. Togo is also a member of the Economic Community of West African States (ECOWAS) energy framework and the West Africa Power Pool (WAPP).[5]

Table 1.
Power plants in Togo

Name of plant	*Type*	*Installed capacity (kW)*	*Available capacity (kW)*
Lomé A	Thermal	19,683	17,695
Lomé B	Thermal	11,856	10,868
Kara	Thermal	5,480	5,480
Dapaong	Thermal	1,976	1,976
Mango	Thermal	1,280	1,280
Sokodé	Thermal	900	900
Kpime 1	Hydropower	800	800
Kpime 2	Hydropower	800	0
G Kouka	Thermal	320	320
Kpekpleme	Thermal	248	248
Tado	Thermal	248	248
Kougnohou	Thermal	240	240
Gando	Thermal	240	240
Barkoissi	Thermal	240	240
Mandouri	Thermal	200	200
Djarikpanga	Thermal	119	119
Mogou	Thermal	90	90
Takpamba	Thermal	90	90
Dimouri	Thermal	90	90
Djon	Thermal	90	90
Bandjeli	Thermal	90	90
Ahassome	Thermal	80	80
Sabiegou	Thermal	80	80
Saligbe	Thermal	48	48
Yegue	Thermal	45	45
Fare	Thermal	32	32
Total CEET		**45,365**	**41,589**
ContourGlobal	Thermal	100,000	100,000
Lomé TAGS	Thermal	20,000	20,000
Nangbeto	Hydropower	65,000	65,000
Total Togo		**230,365**	**226,589**

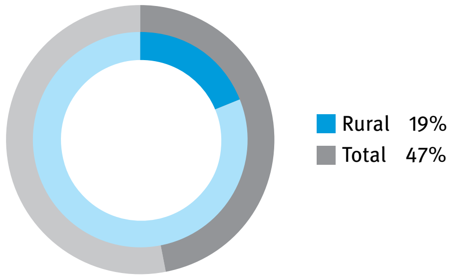
Source: ARSE[4]

The energy sector is supervised by the Ministry of Mines and Energy (MME), and its General Directorate for Energy (Direction Générale de l'Energie) is specifically responsible for policy preparation and implementation in the electricity sector. The Regulation Authority of the Electricity Sector (Autorité de Réglementation du Secteur Electricité, ARSE) is the electricity regulator, whose duties include advising the MME on electricity tariffs, among others.

CEET is the state-owned utility, which is involved in electricity generation but is mainly responsible for and has a monopoly on electricity transmission and distribution. The Electricity Community of Benin (Communauté Électrique du Bénin, CEB) is a bi-national entity established in 1968 to provide generation and transmission for both Togo and Benin. Independent power producers (IPP) have been allowed to participate in the market since 2003. In 2015, a bill was proposed to end the CEB monopoly on purchase of electricity from Togo.[5,7] Contour Global Togo S.A., an IPP currently operating 100 MW of electricity generating capacity, was established in Lomé in 2010.

The national electrification rate in 2016 was approximately 47 per cent, with 87 per cent in urban centres and 19 per cent in rural areas (Figure 2).[8] Electricity prices for residential users, as set on January 1, 2011, vary from 63 XOF/kWh (0.11 US$/kWh) to 120 XOF/kWh (0.22 US$/kWh) depending on the subscription type and monthly consumption.[4]

Figure 2.
Electrification rate in Togo (%)



Source: World Bank[8]

Small hydropower sector overview

While there is no official definition of small hydropower (SHP) in Togo, for the purposes of this report, SHP will include installed capacities up to 10 MW. It should be noted that Togo is in the ECOWAS region, with many states and international documents using the ECOWAS definition of 1 MW to 30 WM. The installed capacity of SHP up to 10 MW in the country is 1.6 MW, while potential is estimated at 144 MW.[4,9] Compared to the results of the *World Small Hydropower Development Report (WSHPDR) 2016*, both installed and potential capacity remained unchanged (Figure 3).

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

Source: ARSE,[5] MME,[9] *WSHPDR 2016*,[10] *WSHPDR 2013*[11]

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

Currently, there is only one SHP plant, which is located in

Kpimé and has two turbines of 0.8 MW each and a generation capacity of 2.6 GWh per year. However, in 2016 only one of the turbines was in operation.[4] SHP potential up to 10 MW has been estimated at 144 MW, but under the ECOWAS definition the potential rises to 186 MW.[9,12] The ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) estimates that the total theoretical hydropower potential of Togo is 596 MW. This includes 27 MW of pico-, micro- and mini-hydropower, 186 MW of small hydropower (1 MW to 30 MW), 73 MW of medium to large hydropower and 310 MW of potential not suitable for development.[12]

CEET identified seven economically feasible small hydropower projects with a total potential capacity of 40 MW (Table 2).[13] Under the technical assistance of the European Union eight potential sites were studied. These include three small-scale sites with capacity up to 10 MW (7.65 MW Wawa SHP, 5.8 MW Baghan SHP and 3.6 MW Seregbené SHP) as well as four sites with capacity from 10 MW to 30 MW (24 MW Titira SHP, 24.2 MW Sarakawa SHP, 15.9 MW Kpessi SHP and 17.1 MW Kolo-Kopé SHP).[14]

Table 2.
Potential SHP sites in Togo

Site name	*Potential capacity (MW)*
Glei	2
Amou Oblo	2
Landa Pozanda	4
Banga	6
Tomegbe-Akloa	8
Kpessi	8
Danyi-Konda	10

Source: Ministry of Economy and Finance[13]

Renewable energy policy

On 8 August 2018, the National Assembly approved the Renewable Energy Policy, which outlines the legal framework for electricity generation from renewable energy sources, both for own and commercial use. The policy addresses all sources of renewable energy, including solar, wind, thermal, tidal 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 (l'Agence Togolaise d'Électrification Rurale et des Énergies Renouvelables, AT2ER), ARSE, the German Agency for International Cooperation (GIZ) and ECREEE.[15,16]

Barriers to small hydropower development

The Government is making efforts in order to promote the use of SHP. However, there are several barriers that need to be taken into account, as outlined below.

- A lack of thorough and updated information regarding potential SHP sites;
- A lack of an accurate geographic information system survey;
- The dilapidation of transport and distribution lines;
- A lack of a clear institutional and legal framework for the development of SHP;
- Limited number of incentives for private investment;
- Poor financial access for longer investment periods.[10]

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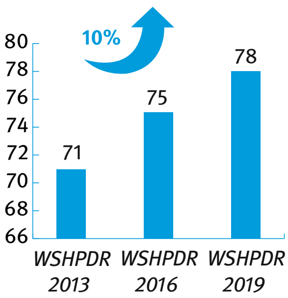
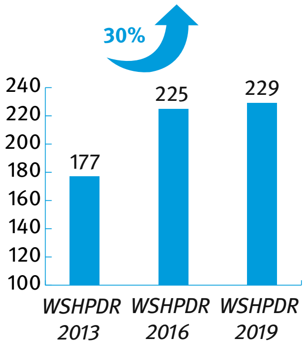
World Small Hydropower Development Report 2019

The ***World Small Hydropower Development Report (WSHPDR) 2019*** is an update of the Report's first two editions in 2013 and 2016. The WSHPDR 2019 contains 166 national reports and 20 regional reports, with 21 new countries added since the first edition.

World SHP installed capacity (GW)



World SHP potential (GW)



- The Report is available on **www.smallhydroworld.org;**
- More than 230 experts and organizations have been involved;
- The Report covers **20 regions and 166 countries**;
- Every country report provides information on:
  a) Electricity sector;
  b) Small hydropower sector;
  c) Renewable energy policy and;
  d) Barriers to small hydropower development.

A special report with **Case Studies** is added to the WSHPDR 2019, showing the different roles small hydropower can play in achieving the SDGs.

Small hydropower for a better world

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