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ON SMALL HYDROPOWER

World Small Hydropower Development Report 2022

Southern Africa

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Southern Africa

Countries: Botswana, Eswatini, Lesotho, Namibia, South Africa

INTRODUCTION TO THE REGION

South Africa is the largest economy in the region by a wide margin, with a robust electricity sector. Thermal power, mainly from coal-fired power plants, accounted for approximately 82 per cent of installed capacity and 86 per cent of generation in 2021. The country also operates the region's only nuclear power plant with an installed capacity of 1,940 MW. The country has some of the highest rates of electricity access in the region, but rural areas still lag behind the rest of the country. Imports of electricity from South Africa contribute a significant share of the electricity supply of all other countries in the region, with Lesotho importing over 50 per cent and Eswatini nearly 80 per cent of their electricity from South Africa. Regional electricity generation is dominated by state-owned companies. The public utility of South Africa ESKOM, the single-largest regional power producer, operates over 89 per cent of the generating capacity of South Africa while the rest is operated by independent power producers (IPPs) and municipalities.

Hydropower development in the region displays some notable characteristics tied to the regional dependence on electricity imports from South Africa. In South Africa itself, hydropower plays a supplementary role, accounting for only 6 per cent of capacity and 3 per cent of generation as of 2021. At the same time, hydropower accounts for the majority of all domestic electricity generation in Namibia and Eswatini and over 99 per cent in Lesotho, with Namibia additionally investing heavily in solar power. Thus, these three countries have adopted a strategy of sourcing their domestic electricity generation from renewable energy while relying on imported electricity from thermal power for the bulk of their energy needs. Botswana is likewise dependent on electricity imports to a significant extent, but has no domestic hydropower capacity due to climactic and topographical factors and has instead opted to source its domestic generation from coal-fired and diesel-fired power plants.

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

Table 1. **Overview of Southern Africa**

Country	*Total population (million people)*	*Electricity access, total (%)*	*Electricity access, rural (%)*	*Total installed capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower installed capacity (MW)*	*Hydropower generation (GWh/year)*
Botswana	2	62	62	893	3,332	0	0
Eswatini	1	77	70	109	293	69	227
Lesotho	2	45	32	77	389	76	392
Namibia	3	55	35	684	1,818	351	1,288
South Africa	60	85	79	57,214	214,926	3,427	6,182
Total	-	-	-	**58,977**	-	**3,922**	-

Source: *WSHPDR 2022*[1]

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

REGIONAL SMALL HYDROPOWER OVERVIEW

The definition of small hydropower (SHP) in Southern Africa varies across countries. Botswana, Eswatini and Namibia do not have a local definition of SHP, in Lesotho SHP is defined as hydropower plants of up to 10 MW, while in South Africa the up to 40 MW definition is used alongside the up to 10 MW definition. A comparison of installed and potential capacities in the region is provided in Table 2.

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

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed capacity (≤10 MW)*	*Potential capacity (≤10 MW)*
Botswana	N/A	0.0	N/A	0.0	1.0
Eswatini	N/A	8.2	16.2	8.2	16.2
Lesotho	Up to 10 MW	3.8	38.2	3.8	38.2
Namibia	N/A	0.1	120.0	0.1	120.0
South Africa	Up to 40 MW	N/A	N/A	42.0	247.0
Total	-	-	-	**54.1**	**422.4**

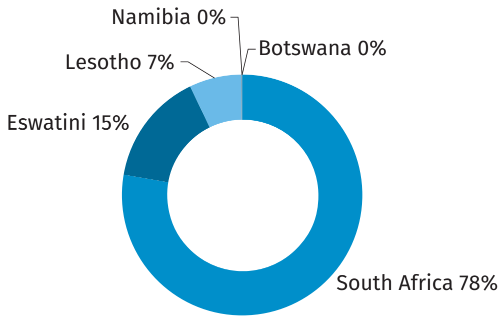
Source: *WSHPDR 2022*[1]

The installed capacity of SHP up to 10 MW in Southern Africa is 54.1 MW, while the estimated potential capacity is 422.4 MW. Relative to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity has increased by 8 per cent, while the estimated potential capacity has remained the same.

The role of SHP in the Southern Africa region varies from country to country and is heavily influenced by economic and environmental factors. Botswana and Namibia both have little to no existing SHP capacity due to low population densities and semi-arid conditions predominating across much of their territory. South Africa operates the majority of the region's installed SHP capacity, but the country's SHP capacity is low relative to that of large hydropower and other energy sources and plays a minor role in the domestic electricity supply. SHP provides a substantial share of the total installed electricity capacities of Eswatini and Lesotho, with both countries possessing significant hydropower resources, but the role of SHP in these two countries should not be overstated due to their heavy reliance on electricity imports. The overwhelming share of SHP potential in the region (87 per cent) is represented by South Africa and Namibia. Significant potential may additionally exist in Botswana but has not been confirmed in detailed studies.

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

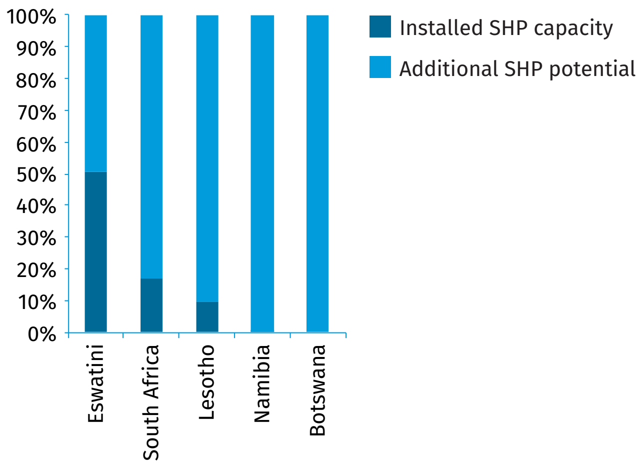
Figure 1. **Share of Regional Installed Capacity of Small Hydropower up to 10 MW by Country in Southern Africa (%)**



Source: *WSHPDR 2022*[1]

Note: Botswana not included due to absence of installed SHP capacity.

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



Source: *WSHPDR 2022*[1]

There are no SHP plants in **Botswana**. Hydropower potential in the country is low due to prevailing topographical features and climatic conditions. One study has identified an SHP potential of approximately 1 MW in the northern part of the country, while a more recent, continent-scale study suggested a significantly higher theoretical potential of 1,289 MW for SHP up to 10 MW. However, this latter figure is likely an overestimate and further detailed studies are necessary that account for current climatic conditions and economic constraints.

The installed capacity of SHP up to 10 MW in **Eswatini** is 8.2 MW from four SHP plants, of which one has been decommissioned but is still technically operational. Most of the existing plants were constructed between 1950 and 1990 and no new SHP plants have been commissioned in recent years, with hydropower development focusing on larger projects. Undeveloped SHP potential was estimated at 8 MW in 2001, with an array of potential micro-, mini- and small hydropower sites identified in subsequent studies. The total SHP potential of the country following the up to 10 MW definition, including existing capacities, is thus estimated at 16.2 MW, indicating that approximately 51 per cent has been developed.

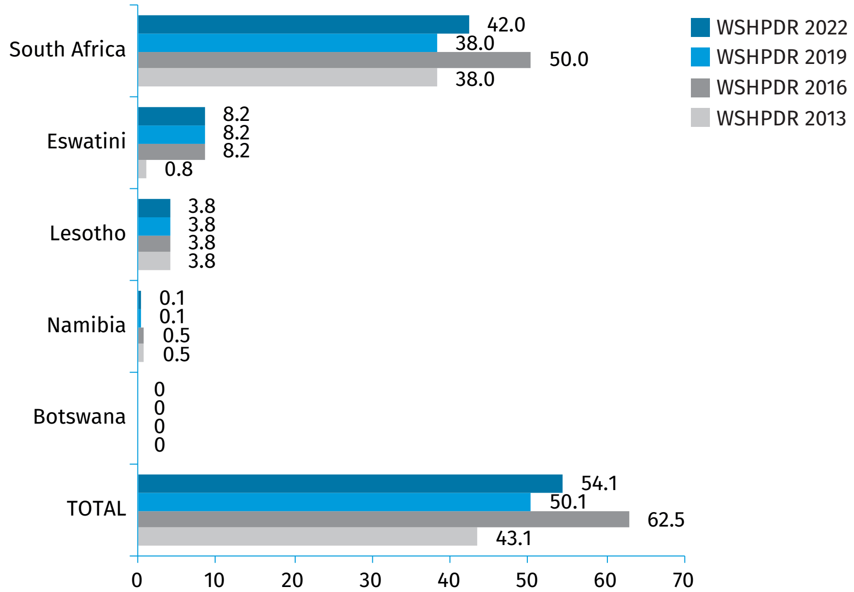
Lesotho has an installed SHP capacity of 3.8 MW from five SHP plants, of which only two plants with a total capacity of 2.2 MW are operational. The potential capacity of the country, including existing plants, is estimated at 38.2 MW, indicating that 10 per cent of SHP potential up to 10 MW has been developed. No new SHP plants have been built in the last two decades, but plans for the rehabilitation of currently non-operational plants are in place.

Namibia has a single SHP plant with an installed capacity of 0.05 MW. The role of SHP in the country's electricity sector is negligible. Namibia has several perennial rivers, one of which hosts a large hydropower plant, but smaller streams appropriate for SHP development are rare as the country is one of the driest and water-stressed in the region and globally. Plans have been proposed to develop 13 SHP plants on the Orange River with a total capacity of 120 MW.

In **South Africa**, the installed capacity of SHP up to 10 MW stood at 42 MW as of 2021, while potential capacity was estimated at 247 MW, indicating that 17 per cent of the known potential is currently utilized. A large number of SHP plants exists throughout the country, but the operational capacity has fluctuated considerably over the past 60–70 years as old plants have been decommissioned and new ones constructed in their place. Many operational plants are located on private land and are not connected to any private grid, supplying power for self-consumption to commercial entities such as mines and resorts. The SHP sector in the country has seen an increase in activity starting with 2009 following decades of neglect, in part due to the promotion of renewable energy sources under the REIPPP programme implemented by the Government. Several new SHP plants have been constructed in recent years.

Changes in the installed SHP capacities of countries in the Southern Africa region compared to the previous editions of the *World Small Hydropower Development Report (WSHPDR)* are displayed in Figure 3.

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



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

Climate Change and Small Hydropower

In South Africa, the Western Cape region is expected to see a 13 per cent decline in the average annual runoff, while the eastern coast will experience an increased risk of flooding. Countries in the Zambezi River basin, which includes Namibia and Botswana, have already experienced climate change, especially rainfall variability. The projected continuous rise in evaporation and evapotranspiration due to the increased temperatures could spur higher water stress in the region. However, the impacts on runoff are yet uncertain.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

In **Botswana**, SHP development is hindered by existing climatic and topographic conditions, which include the flat nature of the terrain with few perennial rivers, as well as by lack of detailed studies of SHP potential.

Eswatini has considerable hydropower resources including untapped SHP potential, but development of SHP in the country is hindered by limited private sector investment, reliability issues with the national electricity grid, and lack of detailed data on sites in need of refurbishment. However, there is renewed interest in SHP development in the country, particularly in the rehabilitation of old SHP plants. This interest is driven in part by rising electricity prices and has resulted in several recent studies assessing undeveloped SHP potential.

The SHP potential of **Lesotho** is likewise significant, relative to the size of the country and existing electricity demand. However, a variety of factors have prevented this potential from being realized, including lack of government planning and local technical capacity for SHP development, difficulty of access to potential sites and small size of the electricity market in the country. Additionally, existing hydropower resources are increasingly stressed by climate change.

Namibia has significant undeveloped SHP potential, but economic factors and a lack of a legislative framework for SHP development have hindered its realization. An additional barrier is that most significant hydropower resources are shared with neighbouring countries, while inland hydropower resources are rare and the country's water resources in general are stressed by variability induced by climate change. At the same time, government policy is broadly supportive of renewable energy development and provides incentives in the form of renewable energy funds and feed-in tariffs.

The main barriers to SHP development in **South Africa** are the lengthy and complicated licensing procedures as well as a lack of interest in financing SHP projects on the part of local banks. Nonetheless, SHP is considered an attractive option for electricity producers in the country alongside other renewable energy sources due to the high relative cost of power generation from fossil fuels. Additional incentivization of SHP is not required and a well-established bidding process for RES projects (REIPPP) has been in place for over a decade. Considerable undeveloped SHP potential remains in the country, particularly on existing water supply infrastructure, which South Africa has in abundance.

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Botswana

Mareledi Gina Maswabi, Department of Energy

KEY FACTS

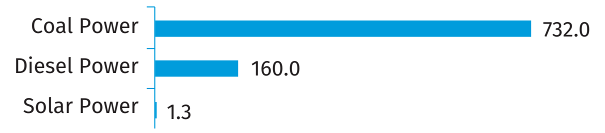
Population	2,351,625 (2020)[1]
Area	581,730 km² [2]
Topography	Botswana is generally flat with a mean altitude of 1,000 metres. A large plateau of approximately 1,200 metres in height divides the country into two distinct topographical regions. The eastern region is hilly, with bushland and grasslands, whereas to the west lies the Okavango Swamps and the Kalahari Desert.[3]
Climate	Botswana has a semi-arid and subtropical climate with both wet and dry conditions. The semi-arid condition makes the climate highly dynamic with variable and sometimes extreme weather. During the dry season, which lasts from April to October in the south and up to November in the northern part, day temperatures can rise to 38 °C and higher, reaching 44 °C on rare occasions in some areas. The winters are dry and clear-skied. Since there is no cloud cover, the air is warmer during the daytime and colder at night. Early mornings have temperature averages 4 °C.[4]
Climate Change	Botswana is vulnerable to climate change, particularly to increasing temperatures and fluctuating rain patterns. Studies show decreased rainfall throughout the country, associated with decreases in the number of rainy days.[5]
Rain Pattern	In Botswana, rains are experienced during summer, peaking in January and February. Rainfall appears to be highly regional, unpredictable and sporadic. The south-west experiences the least average annual rainfall of less than 220 mm, while the north-eastern region receives the highest rainfall averaging 500 mm. The mean annual rainfall ranges from a maximum of over 650 mm in the extreme north-east of the Chobe District to a low of less than 250 mm in the extreme south-west of the Kgalagadi District. There is little to no rain during winter and humidity is low, typically 20–40 per cent. Annual rainfall trends indicate a general decline.[4,6]
Hydrology	Due to its low topography, the country's water storage capacity is one of the lowest in the region. Water sources consist mainly of surface water from rivers of varying sizes, pans and dams, and deep water in aquifers, some of which are non-rechargeable and fossil in nature.[7] The Chobe River in the north, the Limpopo in the south-east and the Okavango in the north-west are the only year-round sources of surface water. These perennial rivers are shared with neighbouring countries. The shared river basins include Okavango, Zambezi, Orange-Senqu and Shashe-Limpopo.[8] The total dam-water capacity is currently estimated at 800 mm³, while the underground capacity (developed resources) is at 131,290 m³/day. The lack of further economical dam sites in Botswana represents a cap in water storage capacity. Waste water makes up 16 per cent of all water supplies, of which just 20 per cent is reused.

ELECTRICITY SECTOR OVERVIEW

Botswana is endowed with abundant coal and solar energy resources. Coal reserves are estimated at approximately 212 billion tons and approximately 2.7 trillion cubic metres of coal-bed methane (CBM) have also been recorded.[9] Besides coal and CBM, there are no other proven reserves of possible fossil fuel resources such as natural gas or oil. There is an abundance of solar power potential countrywide as well as a significant potential from wind power and bioenergy, which is underdeveloped. Countrywide average direct normal irradiance (DNI) solar potential is 6.83 kWh/m² per day with the highest annual sums in the south-western parts of the country.[10] The lowest values are in the extreme eastern parts; however, these remain on a par with the highest resource areas of Europe. Annual energy production from wind is estimated at above 4.5 GWh per year. The theoretical potential of biomass is estimated at 32 million GJ per year, with the use of livestock residues (manure) offering the highest practical opportunity for energy production. Municipal solid waste can also contribute significantly towards energy generation at the city level.

Electricity consumption in Botswana stood at approximately 4,505 GWh per year in 2020 and is expected to reach 8,637 GWh per year by 2040 driven by economic growth.[11] Demand stands at 600 MW and installed capacity stands at 893.3 MW, with 732 MW coming from coal (Morupule A and B power plants), 160 MW from diesel (Orapa and Matshelagabedi plants) and 1.3 MW from solar power (Figure 1).[11,13] There is still a significant amount of power imported from neighbouring countries to augment local supply since the coal-fired plants are not generating to maximum capacity. Morupule A, with a total capacity of 132 MW and a lifetime ending in 2026, is expected to supply 1,020 GWh when fully operational, but on average only delivers approximately 843 GWh of electricity per year.[12] Morupule B, with an installed capacity of 600 MW (4 units of 150 MW) is under remedial works and has not worked to its full capacity since its commissioning in 2014. To date, Morupule B provides approximately 2,299.5 GWh per year and is expected to operate fully by the year 2023. The Orapa (90 MW) and Matshelagabedi (70 MW) emergency diesel-peaking plants were commissioned in 2010 and 2011, respectively. They were intended to mitigate the possible risk of supply shortfall during the Morupule B power plant remedial works period.

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



Source: BCP[13]

At the moment, the share of renewable energy in electricity generation is very insignificant and precise figures on solar power generation in the country are not reported on systematically. In 2019, total electricity generation stood at 3,332 GWh, of which solar power accounted for less than 0.2 per cent (Figure 2).

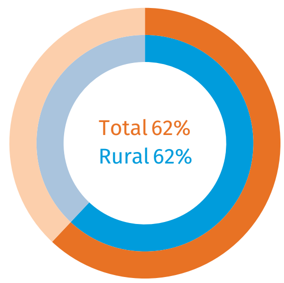
Figure 2. **Annual Electricity Generation by Source in Botswana in 2019 (GWh)**

Source: IRENA[14]

The overall national electricity access rate is 62 per cent, with 61.56 per cent in urban areas and 61.60 per cent in rural areas (Figure 3).[9] The Government has committed to an ambitious target of achieving 100 per cent national electricity access by 2030.[15] To meet this target, it is expected that 30 per cent of the rural population's access will be provided by solar home systems and a further 7 per cent of the rural population will be served by mini-grids.[16]

Having depended on imports from neighbouring countries for a long time, Botswana is now striving for self-sufficiency in electricity. Since 2016, most of the country's electricity needs are met by local generation through a state-owned entity, namely, Botswana Power Corporation (BPC), mainly from the two coal power plants (Morupule A and Morupule B), augmented by the two diesel-operated peaking plants (Matshelagabedi and Orapa). BPC is responsible for the generation, transmission and distribution of electricity and currently holds the sole rights to transmission and distribution. BPC is also involved in the promotion of the involvement of individual power producers (IPPs) in the field of renewable energy.

Figure 3. **Electrification Rate in Botswana in 2021 (%)**



Source: Ministry of Mineral Resources, Green Technology and Energy Security9

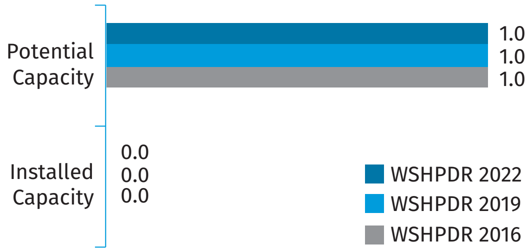
The Electricity Supply (Amendment) Act of 2007 allows for IPPs to partake in generation even though, to date, there is no IPPs playing a role in the electricity sector of Botswana.[17] In accordance with the Electricity Supply Act and the Botswana Power Corporation Act, Botswana Energy Regulatory Authority (BERA) regulates the production, transmission, distribution and selling of electricity through the BERA Act of 2016.[18] An Integrated Resource Plan (IRP) of 2020 outlines the country's power build programme for a period of 40 years, taking into account generation from various energy sources.[19]

The Southern African Development Community (SADC) has developed a competitive electricity market for the region since 2004. Regional electricity prices are analyzed as part of the Southern African Power Pool (SAPP) Plan, which seeks to identify a core set of generation and transmission investments of regional significance that can provide adequate electricity supply and support enhanced integration and power trade in the region. In line with this, Botswana aims to diversify and increase economic development by securing competitive, cost-reflective and sustainable electricity prices. As at June 2020, the price of electricity in Botswana was 0.109 USD/kWh and 0.130 USD/kWh for households and businesses, respectively.[20]

SMALL HYDROPOWER SECTOR OVERVIEW

Due to its aridity, Botswana does not have any hydropower plants and there is no advocacy for hydropower development in the existing energy policies and plans. The potential SHP capacity of the country is estimated at 1 MW.[21] No changes in the small hydropower (SHP) sector in the country have taken place since the *World Small Hydropower Development Report (WSHPDR) 2019* (Figure 4).

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



Source: Jonker Klunne,[21] Korkovelos et al.,[22] *WSHPDR 2016*,[23] *WSHPDR 2019*[24]

It has been reported that there is potential for a 1 MW site in the northern part of the country.[21] A more recent geospatial study showed a significantly higher theoretical potential: 70.4 MW for mini-hydropower (0.1–1 MW) and 1,218.6 MW for SHP (1.01–10 MW).[22] This study was undertaken at a continental scale and likely overestimates the amount of water resources available under the current climatic conditions. A thorough, more focused research on hydropower potential in Botswana is needed and would help inform policy making around the development of hydropower in the country.

The current backup power plants in Botswana are relying on diesel fuel and replacing these with cleaner options such as hydropower would assist the country meet its climate and sustainable development goals while ensuring reliable electricity supply. However, lack of hydrological resources in the country is a key barrier and disincentive.

RENEWABLE ENERGY POLICY

The Ministry of Mineral Resources, Green Technology and Energy Security, through the Department of Energy is the coordinator of all development activities in the sector. The Government of Botswana recognizes the importance of limiting activities that could harm the environment as presented in Vision 2036 and the Eleventh National Development Plan (2017–2023).[25,26] The Nationally Determined Contributions (NDC) of Botswana presents a commitment of 15 per cent greenhouse gas emissions reduction by 2030, using 2010 as a baseline.[27] The NDC recognizes the energy sector as the target as it is the largest contributor to the country's total emissions.

Considering the abundance of solar power, renewable energy is prioritized in the energy sector plans. The National Energy Policy of 2021 advocates for renewable energy development through private sector participation in the electricity sector, including IPPs, to expand generation capacity.[9] According to the Renewable Energy Strategy of Botswana, the development of large-scale grid-connected renewable energy may be expected to contribute in the order of 20 per cent of total electricity consumption in Botswana by 2030, a target that would likely be met almost entirely via large-scale solar generation.[10]

The existing policies are silent on energy generation from hydropower plants considering the scarcity of the water resource in the country. Despite the potential being there, it is unlikely that any hydropower projects will be developed in Botswana in the near future.

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

In 2012, Botswana developed a renewable energy feed-in tariff (FIT), which, however, was never effected due to the high estimated subsidy costs. At the moment of writing of this chapter, the FIT was undergoing review. Guidelines have been developed for rooftop solar power and biofuels, but there is no guideline in place for wind power or hydropower generation.[28]

Effective implementation of renewable energy will require public-private partnerships and this creates room for local and foreign investment. There is currently no articulated framework for public-private partnerships (PPPs) in the power sector, nor are there any standard power purchase agreements (PPAs) in place. Development of such critical policy implementation tools is vital especially given that the envisaged projects stipulated in the country's IRP have been endorsed by the Cabinet for implementation through IPPs.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Regional changes in rainfall and water availability, protracted drought events, significant variation in temperature regimes and more frequent and severe weather events are the climate change impacts that can affect the hydropower sector. These effects have an impact on the future sustainability of any SHP development, which could discourage potential investment.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The key barriers to SHP development in the country include:
- No existing hydropower plants in the country;
- Lack of plans towards hydropower development;
- Flat topography;
- Limited water resources.

At the same time, networked micro-hydropower could still be a possibility despite the existing natural limitations. New studies could clarify the availability of SHP potential.

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Eswatini

Wim Jonker Klunne, Hydro4Africa

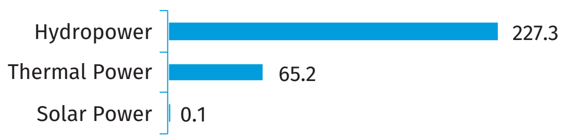
KEY FACTS

Population	1,148,130 (2019)[1]
Area	17,360 km^2[2]
Topography	The Kingdom of Eswatini 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 lowest point is the Great Usutu River, at 21 metres above sea level, and the highest is Emlembe Mountain, at 1,862 metres.[3]
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]
Climate Change	Despite not emitting large quantities of greenhouse gas emissions, Eswatini is facing severe climate change impacts. Variable precipitation patterns, droughts, desertification, higher temperatures and increased storm intensities have already affected the country's population and key economic sectors. As a developing, lower-middle income country, with 69 per cent of the population living below the poverty line, Eswatini has little capacity to cope with these impacts.[4]
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 region, but decreases towards the east with the Lowveld region averaging between 500 mm and 900 mm.[3]
Hydrology	Major perennial rivers, which have their sources in South Africa, flow through the country to the Indian Ocean. They are the Lomati, Komati, Umbuluzi and Usutu. The Usutu has the largest catchment in the country, with three main tributaries: the Usushwana, Ngwempisi and Mkhondvo.[5]

ELECTRICITY SECTOR OVERVIEW

The Eswatini electricity grid is supplied by the Eswatini Electricity Company (EEC) through four hydropower plants (Ezulwini of 20.2 MW, Maguga of 19.5 MW, Edwaleni of 15.0 MW and Maguduza of 5.6 MW), Ubombo Sugar Limited (40.5 MW of biomass supplemented by coal), the Wundersight's Buckswood 100 kW solar photovoltaic (PV) plant and 8.2 MW of small hydropower (SHP) capacity. The country's total installed capacity as of 2020 was 109.1 MW (Figure 1). In addition, there are several private self-generating plants owned by the industrial sector. In 2021, the new 10 MW Lavumisa solar PV plant owned by the EEC began commercial operation.[6,7]

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

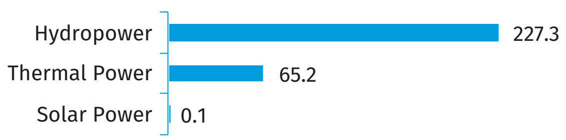


Source: EEC[6]

Note: Thermal power includes generation from coal and biomass; data do not include privately owned self-generation.

The local generation is augmented by imports through the Southern African Power Pool (SAPP), with South African utility ESKOM as the major source of electricity. The total electricity generated in the country reached 292.6 GWh at the end of the 2019/2020 financial year (Figure 2). Eswatini is still highly reliant on electricity imports, with approximately 1,028 GWh of electricity imported in 2020.[6]

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



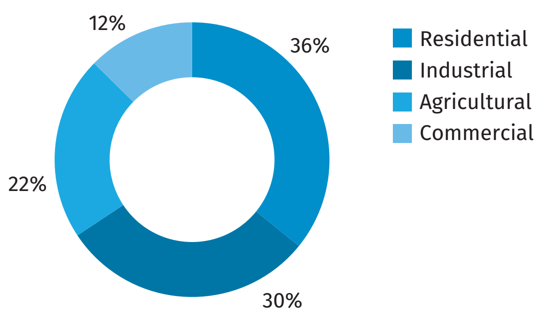
Source: EEC[6]

Note: Thermal power includes generation from coal and biomass; data do not include privately owned self-generation.

The four hydropower plants of EEC have a total installed capacity of 60.3 MW and contributed 17.2 per cent to the country's total electricity supply (including imports) in the financial year 2019/2020.[6] Total hydropower generation in 2019/2020 amounted to 227.3 GWh, compared to 266.1 GWh in the previous financial year. The EEC hydropower plants are located in the Usuthu River catchment basin (Ezulwini, Edwaleni and Maguduza plants) and in the Komati basin (Maguga plant).[6]

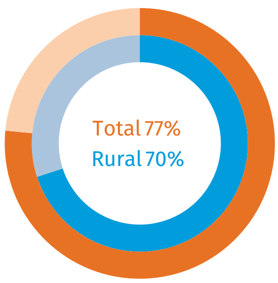
In 2020, the residential and industrial sectors dominated national electricity consumption, with 36 and 30 per cent of the total, respectively (Figure 3).[6] The overall electrification rate is estimated at approximately 77 per cent, with approximately 97 per cent of the urban areas and 70 per cent of the rural areas electrified (Figure 4).[8] 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 sawmill industries.

Figure 3. **Electricity Consumption by Sector in Eswatini in 2020 (%)**



Source: EEC[6]

Figure 4. **Electrification Rates in Eswatini in 2020 (%)**



Source: World Bank[8]

As of 1 April 2020, the consumer tariffs ranged from 1.0887 SZL/kWh (0.077 USD/kWh) to 2.4144 SZL/kWh (0.17 USD/kWh) (Table 1) for non-time of use (TOU) customers, while the price for TOU customers can be as high as approximately 5 SZL/kWh (0.35 USD).[9]

Table 1. **Consumer Tariffs in Eswatini in 2020/21**

Tariff type	*Facility charge per month (SZL (USD))*	*Energy charge per kWh (SZL (USD))*
Life line		1.089 (0.08)
Domestic		1.806 (0.13)
General purpose	208.46 (14.75)	2.414 (0.17)
Small commercial prepayment	208.46 (14.75)	2.414 (0.17)
Small commercial credit meter	416.93 (29.51)	2.414 (0.17)

Source: EEC[10]

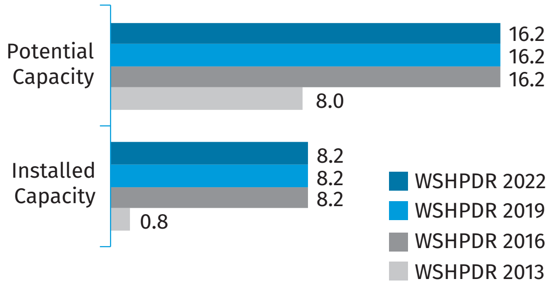
EEC was established in 2007 as the Swaziland Electricity Company (SEC) by the Swaziland Electricity Company Act of 2007.[11] It currently operates as a monopoly with regards to the import, distribution and supply of electricity via the national power grid and owns the majority of the country's power plants. There are also a number of private power plants. A substantial amount (almost 25 per cent) of the energy used in the country 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 to ensure proper oversight over the state company as a corporate entity.[12] 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, terms and conditions of operating a licence;
- Monitor the performance and efficiency of licensed operators.

SMALL HYDROPOWER SECTOR OVERVIEW

There is no official definition for SHP in Eswatini, therefore, this chapter assumes a definition of plants less than 10 MW. The installed capacity of SHP in the country is currently 8.205 MW, including the decommissioned but still technically operational 0.5 MW plant at Mbabane.[13] Additional potential capacity is estimated to be at least 8 MW, indicating that more than 50 per cent of the available potential has been developed so far.[14] In comparison to data from the *World Small Hydropower Development Report (WSHPDR) 2019*, both the installed and potential capacities have remained the same (Figure 5).

Figure 5. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in Eswatini (MW)**



Source: Jonker Klunne,[13] Knight Piesold Consulting,[14] WSH*PDR 2013*,[15] *WSHPDR 2016*,[16] *WSHPDR 2019*[17]

Currently, only six hydropower plants are operational in the country, three of which have capacities of less than 10 MW (Table 2).[13] EEC operates the grid connected to the Ezulwini (20.0 MW), Maguga (19.5 MW) Edwaleni (15.0 MW) and Maguduza (5.6 MW) plants. The Mbabane plant of 500 kW was decommissioned by EEC in December 2010 as it was no longer able to operate profitably.[18] In 2018, the African Development Bank submitted a concept note to the Green Climate Fund, which includes a proposed rehabilitation of the Mbabane plant at an estimated cost of USD 7 million. At the moment the AfDB Is trying to mobilize co-funding for the project before it can be considered for approval.[19] Two private SHP plants are also in operation: the 800 kW plant of Swaziland Plantations and the 1.305 MW plant of Ubumbo Sugar in Big Bend.[13]

Table 2. **List of Small Hydropower Plants in Eswatini**

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Plant type*	*Operator*	*Launch year*
Ezulwini	Ezulwini valley	20.0	–	Pelton, storage	EEC	1985
Maguga	Hhohho	19.5	50 –90	Francis, storage	EEC	2006
Edwaleni	Manzini	15.0	141	Dam with run-of-river	EEC	1969
Maguduza	Manzini	5.6	–	Dam with run-of-river	EEC	1969
Ubumbu Sugar	Big Bend	1.3	28	Cross-flow, run of river	Ubumbu Sugar	1986
Swaziland Plantations	Pigg's Peak	0.8	76	Francis, storage	Swaziland Plantations	1952
Mbabane*	Mbabane	0.5	–	–	EEC	1954

Source: Jonker Klunne[13]

Note: *decommissioned.

Both the Edwaleni and Maguduza plants feed from the Greater and the Little Usutu Rivers. 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 plants' capacity to provide peak power but also caused severe wear on the turbines.[20] Currently, the plants are free of siltation problems. The Edwaleni plant also comprises three sets of diesel generation facilities (2 x 4.5 MW + 1 x 0.5 MW), however these are seldom utilized by EEC 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-metre-high dam, before being fed into a 1.75 metre in diameter, 300-metre-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/s 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 synchronized to the EEC system and feeds a 16-kilometre-long, 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.[21] 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 plant on the Great Usuthu River was commissioned in 1986 and consists of two 728 kW Ossberger turbines. The plant provides power to the sugar processing facilities in Big Bend.[13]

Feasibility studies are currently ongoing for the Ngwempisi cascading project, which 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.[22] The success of the existing Maguga hydropower plant has also encouraged EEC to consider exploring the potential of adding extra generating equipment on the existing plant as well as constructing another power plant approximately 7 kilometres downstream of the current one. An engineering consulting firm has been engaged to carry out a full feasibility study, including a further investigation of the potential to develop a 10 MW site down the Maguga plant, which will utilize the existing Maguga dam. The intention is to take advantage of the remaining capacity below 35 per cent of the Maguga dam level at the downstream hydropower plant.[6] Expanding the Maguga plant will increase the local generation capacity and decrease the dependence on imported power. The extra generation units will also ensure that some of the excess water, which normally spills during the rainy seasons, is used to generate power. In addition, T-Colle Investments of Mbabane is looking to build an SZL 5 million (USD 575,000) hydropower plant with a capacity of 360 kW on a canal in the central Manzini region. The firm will charge EEC SZL 0.70 (USD 0.081) per kWh for the first three years of production (Table 3).[23]

Table 3. **List of Planned Small Hydropower Projects in Eswatini**

Name	*Location*	*Capacity (MW)*	*Plant type*	*Development stage*
Maguga extension	Maguga	10.00	–	Feasibility study
Maguga downstream	Maguga	10.00	Run-of-river	Feasibility study
Lubovane		0.85	–	Feasibility study
Dwaleni's Ferreira Canal	Manzini	0.36	Run-of-river	Feasibility study
Mbabane	Mbabane	0.05	–	Feasibility study

Source: Jonker Klunne[13]

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.[21] The latest full study on hydropower potential in Eswatini however was carried out by Knight Piesold Consulting in 2001. The study showed that there is 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.[24] As part of its objective to expand the hydropower sector, the Ministry of Natural Resources and Energy (MNRE) has, based on the findings of Knight Piesold Consulting, built a database of potential sites. Initially, 35 candidate sites were identified, ranging from 32 kW to 1.5 MW. This was further reduced to 26, based on the potential for electricity generation. Four have been identified as viable projects and are being promoted by MNRE: Lusushwana River (300 kW), Mpuluzi River (155 kW), Usutu River (490 kW) and Mbuluzi River (120 kW minimum) (Table 4).[25]

Several studies have been undertaken to estimate the total hydropower potential of Eswatini. In 1970, the UNDP financed a study by Engineering and Power Development Consultants, which identified 21 potential sites.[20] Based on existing information, the Environmental Centre for Swaziland (now Eswatini Environment Authority) estimated a gross theoretical potential of 440 MW and technically exploitable potential of 110 MW, of which 61 MW is economically exploitable.[25]

Table 4. **List of Small Hydropower Sites Available for DDevelopment in Eswatini as of 2021**

Name	*Potential capacity (MW)*	*Type of site (new/ refurbishment)*
Lusushwana River	0.300	New
Mpuluzi River	0.155	New
Usutu River	0.490	New
Mbuluzi River	0.120	New

Source: IRENA[26]

RENEWABLE ENERGY POLICY

In 2007, MNRE formulated a strategic framework and action plan with the aim to:

- Establish a centre for demonstration and education on renewable and sustainable energy;
- Encourage and enhance, where applicable, topics on renewable energy and energy in general in educational and training curricula;
- Maximize the use of renewable energy technologies wherever they are viable;
- Promote greater understanding and awareness of renewable energy resources and associated technologies;
- Develop and maintain accurate data on renewable energy resources and make them available to all, in order to make informed policy decisions regarding the sustainable energy use and supply;
- Develop woodlots in areas where there is an acute fuel wood shortage.[27]

A more recent Master Energy Plan 2034 was developed in 2018 with the aid of the International Renewable Energy Agency (IRENA).[28] The plan asserts that under a limited import scenario, 676 MW of domestic capacity must be secured if projected demand is to be met in 2034 while assuring adequate reserves. Under the policy's limited import 2 scenario, hydropower is to make up 120 MW of installed capacity by 2025.

There are no specific regulations pertaining to SHP in the country, nor is there available information on cost and specific financial mechanisms. Financial incentives for other off-grid renewable solutions are only available in the form of development finance, as demonstrated by projects funded from UNDP and the World Bank.[29]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

The climate crisis is likely to affect the river flow rate in the country. This foreseen fluctuation will affect hydropower capacity factors and make predictions more difficult.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The hydropower resources of Eswatini have been well documented and with the 2007 electricity sector reforms a legal framework for the introduction of independent power producers has been created. However up until now multiple barriers have made the development of SHP in the country difficult. Some of the most noteworthy barriers include:

- Limited private sector investment;
- Reduced reliability of the national grid;
- Lack of a good overview of potential sites for refurbishment.

The enabling factors include:

- Renewed interest in hydropower as an energy source, as indicated through the recent studies on the Ngwempisi cascading project and the Lower Maguduza plant, suggesting that new developments may progress more positively in the future;
- Increasing electricity prices and the reduced reliability of the national grid have resulted in increased interest in rehabilitation of the old defunct hydropower plants; it can be expected that a number of sites will be economically feasible to rehabilitate.

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Lesotho

Wim Jonker Klunne, Hydro4Africa

KEY FACTS

Population	2,125,268 (2019)[1]
Area	30,360 km^2[2]
Topography	Lesotho is a small country surrounded by the Republic of South Africa. The lowest elevation in the country is at the junction of the Makhaleng and Orange (Senqu) Rivers (at the border with South Africa), which at 1,400 metres is the highest lowest point of any country in the world. Lesotho is the only country that lies entirely above 1,000 metres in elevation. The highest point is the peak of the Thabana Ntlenyana mountain, which reaches an elevation of 3,482 metres. Approximately one quarter of the land area is represented by lowlands located in the west and varying in height from 1,500 to 1,600 metres above sea level. The remaining three quarters are highlands running 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 2,700–3,400 metres.[3,4]
Climate	The climate in the country is temperate 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 to -20 °C in the winter.[5]
Climate Change	Lesotho is expected to experience a change in temperature and precipitation patterns, towards drier and hotter conditions. In addition, the intensity and frequency of extreme events such as floods and droughts are expected to increase, especially in the western and northern lowlands. Water resources will be affected negatively by the reduction of precipitation and increase in temperature. This will result in an increase in evaporation losses and a decrease in runoff and groundwater recharge.[6]
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.[5]
Hydrology	Two of the largest rivers in Southern Africa, the Orange (Senqu) River and the Tugela River, as well as 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 Caledon covering the rest. The Lesotho Highlands Water Project (LHWP) is an ongoing water supply project with a hydropower component, developed in partnership between the Governments of Lesotho and South Africa. It comprises a system of several large dams and tunnels throughout Lesotho and delivers water to the Vaal River System in South Africa. In Lesotho, it involves the Malibamatso, Matsoku, Senqunyane and Senqu Rivers.[4,5]

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, animal 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.[7]

The electricity sector is relatively small with an installed capacity of 77 MW as of 2020 (Figure 1).[8,9] This mainly came from the 72 MW 'Muela hydropower plant linked to and managed by the Lesotho Highlands Water Development Authority (LHWDA) scheme to provide water to South Africa. Peak demand has been seen to reach 167 MW, forcing the Government to meet the deficit through imports from Mozambique and South Africa. In 2019/2020, the Lesotho Electricity Company (LEC) purchased 389.1 GWh from the 'Muela hydropower plant and imported 429.8 GWh from South Africa and 99.5 GWh from Mozambique.[10] 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.[7]

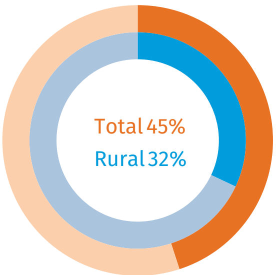
Figure 1. **Installed Electricity Capacity by Source in Lesotho in 2020 (MW)**

Source: Department of Energy,[9] Bureau of Statistics[10]

Hydropower generation in Lesotho has typically been a strong source of generation, but has experienced shortfalls in recent years. In 2018, generation from the 'Muela hydropower plant reached 515.8 GWh, but by 2019 this dropped to 391.7 GWh.[10] Small hydropower (SHP) plants, such as Semonkong, experience the highest generation in summer months. Most of the Semonkong generation in recent years has come from diesel generation, with only 0.06 GWh in 2018/2019 coming from hydropower, representing just 9 per cent of the plant's total electricity generation that year (0.7 GWh).[11] The Mantšonyane SHP plant generation in 2019/2020 was only recorded for January at 0.03 GWh.[10]

Nationwide, approximately 45 per cent of the population had access to electricity in 2019, a revision downwards of 5 per cent from 2018 estimates. Electricity access rates are 76 per cent for urban areas and 32 per cent for rural areas.[12]

Figure 2. **Electrification Rate in Lesotho in 2019 (%)**



Source: World Bank[12]

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 carried out a renewable energy resource assessment (Table 1).[9]

Table 1. **Technical Potential of Low Carbon Technologies in Lesotho under SREP**

Technology	Technical potential (MW)
Utility-scale wind power	2,077
Utility-scale solar PV	118
Micro-solar power technologies	38
Small-scale hydropower	36
Solar power micro-grids	31
Waste to energy	10
Solar power home systems	1
Floating micro-hydropower	0.5
Total	**2,311.7**

Source: Department of Energy[9]

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.[13]

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.[9]

Electricity tariffs in Lesotho vary by consumption category and in 2020/2021 were as shown in Table 2.

Table 2. **Electricity Tariffs in Lesotho in 2022/2021**

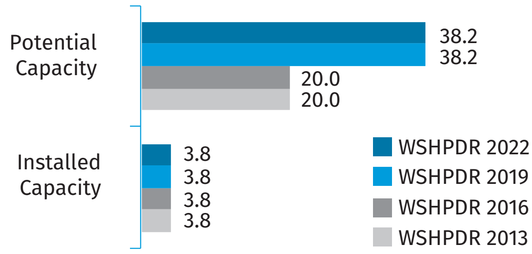
Customer category	*Final electricity price (LSL (USD) per kWh)*	*Increase vs. 2017/2018 rates (%)*
Industrial high-voltage	0.2559 (0.017)	3.0
Industrial low-voltage	0.2767 (0.018)	3.1
Commercial high-voltage	0.2559 (0.017)	3.0
Commercial low-voltage	0.2767 (0.018)	3.1
General purpose	1.6608 (0.110)	3.8
Domestic	1.4782 (0.097)	3.8
Lifeline domestic	0.7273 (0.048)	–
Street lighting	0.8725 (0.057)	3.7

Source: LEWA[14]

SMALL HYDROPOWER SECTOR OVERVIEW

SHP is defined in Lesotho as hydropower plants with capacity of up to 10 MW.[9] As of 2021, the installed capacity of SHP plants was 3.82 MW, of which 2.2 MW was operational, while the potential was estimated at approximately 38.2 MW.[15] Neither installed nor potential capacity estimates have changed since the publication of the *World Small Hydropower Development Report (WSHPDR) 2019* (Figure 3).

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



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

There are five SHP plants in Lesotho: Mantsonyane (2 MW), Tlokoeng (670 kW), Katse (540 kW), Tsoelike (400 kW) and Semonkong (180 kW) (Table 1). However, out of these five, only the Mantsonyane and Semonkong plants are currently operational.[15] As of 2021, the Katse plant (on the Katse dam) is decommissioned due to earlier flooding. The Government of Lesotho engaged with the Japan International Cooperation Agency (JICA) to have it rehabilitated and connected to the national grid. The commencement of the work is expected sometime in 2022.[19]

Table 3. **List of Installed Small Hydropower Plants in Lesotho**

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Plant type*	*Operator*	*Launch year*
Katse (non-operational)	Katse Dam	0.54	–	Reservoir	LHDA	2000
Tsoelike (non-operational)	Qacha's Nek	0.40	–	Run-of-river	LEC	1990
Tlokoeng (non-operational)	Mokhotlong	0.67	–	Reservoir	LEC	1990
Semonkong	Semonkong	0.19	18.0	Run-of-river	LEC	1989
Mantsonyane	Mantsonyane	2.00	35.5	Reservoir	LEC	1989

Source: Jonker Klunne[15]

The Tsoelike hydropower plant is a 400 kW run-of-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 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 electricity system, but has been connected to the South African ESKOM grid since 1997. This cross-border connection has enabled LEC to decommission the plant in 2000 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 670 kW 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 of 500 kVA at Mokhotlong town. 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.[20] 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 lopping 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 6 February 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 with a 1,900 kVA and a 650 kVA generator, 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.[21,22]

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. At the moment, the plant is not in use due to flooding damage and awaiting rehabilitation, which is expected to start in 2022.

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 meters. 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 powerhouse 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 the 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.[23] Under the recently approved World Bank Lesotho Renewable Energy and Energy Access project, the Semonkong plant will be rehabilitated and hybridized with a 1.5 MW solar photovoltaic (PV) plant and storage of 500 kWh. This will allow the customer base to be expanded with an additional 100 customers.[24]

There is a substantial potential for further SHP 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 SHP sites with a combined capacity of 36.33 MW. 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 SHP plant Tsoelike met the eligibility criteria. In addition, the analysis revealed one previously unidentified site (Table 4).[9]

As part of the preparatory work for phase 2 of the Lesotho Highlands Water Project (LHWP), feasibility studies were carried out on the inclusion of pumped storage, such as the Kobong plant. However, the decision was made to defer the pump storage option (due to prevailing economic conditions) and advance the conventional options. This entails one site at Oxbow on the Malibamatšo River and two sites on the Senqu River, all three in the large hydropower category.[25]

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

Name	Location	Potential capacity (MW)	Type of site (new/refurbishment)	Type of plant
Makhaleng 4	Makhaleng	9.1	New	Reservoir
Makhaleng 3	Makhaleng	8.9	New	Run-of-river
Hlotse	Hlotse	6.5	New	Reservoir
Phuthiatsana	Phuthiatsana	5.4	New	Reservoir
Thaba-Tseka	Mali-bamat'so	4.5	New	Reservoir

Source: Department of Energy[9]

RENEWABLE ENERGY POLICY

The Lesotho Energy Policy 2015–2025 noted that renewable energy sources and energy efficiency are expected to play a significant role in the country's future energy plans and explicitly stated the Government's aim of improving access to renewable energy services and technologies. Strategies and programmes include facilitating the establishment of rural energy service companies (RESCOs) and developing a renewable energy programme to support fossil fuel substitution.[9]

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). Many components of this framework have been incorporated in the Energy Act. Moreover, it is expected that the 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 currently ongoing, will assist in creating a more conducive environment for renewable energy.[26,27]

COST OF SMALL HYDROPOWER DEVELOPMENT

Costs of SHP remain high in the country, as elsewhere, since costs of SHP are higher per MW of installed capacity than larger hydropower plants.

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

Much of the financing for projects in the country are reliant on international development aid or project financing.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Poor rainfall in recent years has significantly impacted the hydropower sector, leading the few remaining operational SHP plants such as the Semonkong and the Mantšonyane to significantly decrease generation output. This makes for a poor SHP business case, and puts the future of the sector in jeopardy.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

In general, the conditions in Lesotho can be described as conducive in terms of the legislation framework allowing the operation of independent power producers and distributors.[28] However, it has proven to be difficult for international partners to find viable business models for the development of SHP 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.[29]

However, with the renewed interest in renewable energy, and in particular mini-grids, promising signs are emerging. One of the solar mini-grid developers in the country is about to launch a GIS-based exercise to determine whether some of its solar mini-grids can be hybridized with SHP.

The key barriers to the development of SHP in Lesotho include:

- Poor water resources, leading to poor capacity factors for existing plants;
- 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 skills required for SHP construction, operation and maintenance;
- Low general awareness of SHP as well as of other renewable energy technologies;
- Difficulties in accessing some sites;
- Limited availability of spare parts in the local market;
- Low water levels mean that SHP is no longer viable and existing plants might not generate due electricity.

No clear enabling factors have been identified for the development of SHP in the country.

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Namibia

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

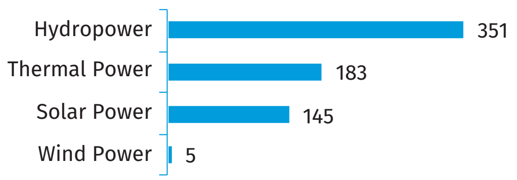
KEY FACTS

Population	2,540,916 (2020)[1]
Area	824,290 km² [2]
Topography	Namibia is characterized by four topographical regions: the Namib desert, the Central Plateau running from north to south with an altitude reaching up to 2,000 metres above sea level, the eastern lowlands that include the Kalahari Desert and, to the north-east, the high rainfall areas of Caprivi and Okavango. The highest mountain in the country is the Brandberg peaking at approximately 2,579 metres above sea level, followed by the Moltkeblick with a height of 2,480 metres.[3]
Climate	Namibia is one of the driest and most arid countries in Sub-Saharan Africa. Characterized by high climatic variabilities with constant droughts, variable temperatures, water scarcity and unpredictable rainfall patterns. With 92 per cent of the land area considered very arid, arid or semi-arid, Namibia is second only to the Sahara Desert in aridity on the continent. The annual temperatures in the country average between 14 °C and 24 °C, with the north averaging 22 °C and the southern coast below 16 °C. Apart from the coastal area, the highest temperatures occur in the wet season in drier areas and right before the wet season in wetter areas. The dry season, when the lowest temperatures occur, lasts from June to August.[4]
Climate Change	Namibia has been experiencing the effects of climate change through increased unpredictability and variability in rainfall patterns, frequent droughts and increased annual temperatures. This has been affecting agriculture, with droughts reducing agricultural productivity and thus leading to reduced income for farmers and death of livestock. The annual mean temperatures have been observed to be increasing since the 1960s, particularly at night-time. The frequency of days with maximum temperatures exceeding 25 °C and 35 °C has been increasing and the frequency of days with temperatures below 5 °C has been decreasing. An increase in overall rainfall scarcity as well as an increase in heavy rainfall events have been observed, with noted changes in onset, duration and intensity of rainfall.[4,5]
Rain Pattern	Due to the arid nature that characterizes Namibia, rainfall is scarce and highly variable and potential evaporation is approximately five times greater than average rainfall. The annual mean rainfall is 279 mm, varying from 650 mm in the north-east to less than 50 mm in the south-west. Rainfall in the Namib Desert area is extremely scarce. Mean monthly rainfall averages 62 mm, 66 mm and 55 mm in January, February and March, respectively. The rainy season in Namibia is from October to April, with minimal rainfall in May and September.[4]
Hydrology	Of the scarce rainfall received in Namibia, 83 per cent is evaporated, 14 per cent is lost through transpiration, 2 per cent is run off into rivers and 1 per cent seeps underground. Within one season, the country can lose 20–85 per cent of its water through evaporation. Namibia has five perennial rivers: the Orange, the Kunene, the Kavango, the Zambezi and the Kwando (also known as Linyanti and Chobe).[6]

ELECTRICITY SECTOR OVERVIEW

The main sources of electricity in Namibia are hydropower, solar power, thermal power and wind power. In 2019, these sources accounted for 71 per cent, 19 per cent, 9 per cent and 1 per cent, respectively, of total electricity production, which amounted to 1,818 GWh (Figure 1). As a country that relies heavily on imported electricity, Namibia imports over 60 per cent of the total electricity consumed from neighbouring countries through bilateral contracts with Eskom of South Africa, Zimbabwe and the Southern Africa Power Pool (SAPP).[7]

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

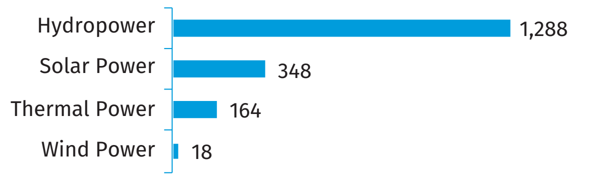


Source: IRENA[7]

In 2017, Namibia decided to update its Energy Policy of 1998 with a more future-oriented one — the National Energy Policy of 2017 (NEP). This new policy aims to usher in a more sustainability-focused approach to the energy sector, while acknowledging the country's reliance on neighbouring countries to meet most of its needs in electricity and the importance of developing and exploiting its own natural energy resources.[8] The NEP is aligned with the country's Vision 2030, an integrated long-term national development strategy that aims to improve the quality of life in Namibia to the level of developed countries by 2030.[10] In order to achieve this, the Government has been making efforts to attract foreign investment to develop the country's own hydrocarbon potential by establishing the country as an attractive destination for both international oil companies and local actors.

Much of the locally generated electricity in Namibia is produced by the Government-owned power utility NamPower, which operates the generation facilities: Ruacana hydropower plant, the Van Eck coal power plant, the Paratus diesel power plant and the Anixas diesel power plant.[9] As of 2020, Namibia had a total installed electricity capacity of approximately 684 MW, of which hydropower, thermal power, solar power and wind power represented 51 per cent, 27 per cent, 21 per cent and 1 per cent, respectively (Figure 2).[7]

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



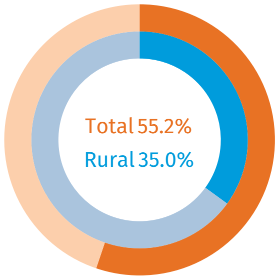
Source: IRENA[7]

NamPower, born out of the South West Africa Water and Electricity Corporation (SWAWEK) in 1996, controls the generation, transmission and supply of energy to the various Regional Electricity Distributors, mines and farms throughout the country. In an effort to be less reliant on imports from South Africa, NamPower has signed power purchase agreements with utilities in neighbouring Zambia, Botswana, Zimbabwe, Zambia, Mozambique and the Democratic Republic of the Congo (DRC). The company has also completed the TransCaprivi Interconnector which directly connects NamPower to the power grids of Zimbabwe and Zambia. NamPower is overseen by the Ministry of Mines and Energy (MME) and regulated by the Electricity Control Board.[11,12]

Since 2019, independent power producers (IPPs) can sell electricity to large power users both locally and internationally, across the national transmission grid. This marks a trend towards the decentralization of electricity production, transmission and supply in Namibia.[12]

The total electrification rate in Namibia was 55 per cent in 2019, with an urban access rate of 75 per cent and a rural access rate of 35 per cent (Figure 3).[13]

Figure 3. **The Electrification Rate in Namibia in 2019 (%)**



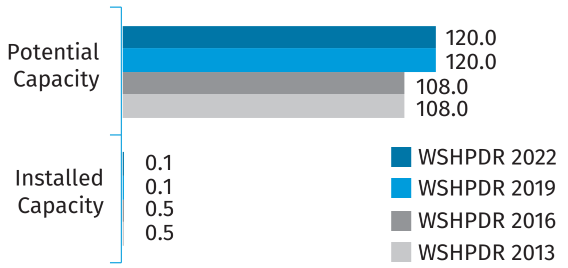
Source: AEP[13]

Electricity tariffs in Namibia are regulated by the Electricity Control Board (ECB), established by the Electricity Act 2 of 2000 and expanded by the Electricity Act 4 of 2007. The ECB's statutory functions are executed through the Technical Secretariat and include the reviewing, setting and approving of all tariffs in the country.[14] The cost of electricity for the end consumer depends on the location, electricity distribution company and specific tariff. In 2021–2022, NamPower distribution tariffs ranged between 1.29 NAD/kWh and 2.29 NAD/kWh (0.089–0.160 USD/kWh), with additional levies and charges applied.[15]

SMALL HYDROPOPOWER SECTOR OVERVIEW

There is no official definition of small hydropower (SHP) in Namibia, therefore, for the purposes of this chapter, a definition of up to 10 MW will be used. There is currently one operational SHP plant in Namibia, with a capacity of 50 kW. Plans have been devised to develop 13 more SHP plants in the country by exploiting the resources of the Orange River, which could have an estimated capacity of 120 MW and generate approximately 380 GWh/year. The installed and potential capacities have not deviated since the *World Small Hydropower Development Report (WSHPDR) 2019* (Figure 4).[16,17]

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



Source: MME,[16] MEFT,[17] *WSHPDR 2013*,[18] *WSHPDR 2016*,[19] *WSHPDR 2019*[20]

The only operational SHP plant in Namibia is located between the village of Divundu and the Angola border, some 20 kilometres upstream the Popa Falls. There are a number of factors affecting the development of SHP including increasing drought periods, scarce rainfall and the location of potential sites at borders with neighbouring countries.[16]

RENEWABLE ENERGY POLICY

Namibia is one of the countries that experiences the highest solar irradiation regime, endowing it with tremendous potential for the development of solar power. The country also has considerable potential for the development of wind power due to strong winds in its coastal areas. There are also numerous hot springs in Namibia that could be harnessed for thermal power and rivers for hydropower development. In order to more efficiently exploit these natural resources for the development of the country, cohesive policies that would tie into the country's Vision 2030 were needed. The Government of Namibia formulated the Renewable Energy Policy (REP) of 2017 to boost the renewable energy sector and signal to local and potential international actors that the country is committed to invest in its natural resources.[21]

In order to implement the REP, further instruments such as the IPP framework and the Energy Efficiency Policy were introduced. The long-term National Integrated Resource Plan (NIRP), adopted in 2016, guides IPPs, power sector planners and electricity customers in Namibia. The REP also synthesizes elements of previously introduced policies such as the Fourth National Development Plan (NDP-4) 2012/2013–2016/17, the Off-Grid Energization Master Plan (OGEMP) of 2007, the National Policy on Climate Change of 2011 and the country's Intended Nationally Determined Contribution to the United Nations Framework Convention on Climate Change (UNFCCC).[21]

Namibia aims to achieve universal electricity access and a 70 per cent share of renewable energy in its generation mix by 2030, with all of it being locally produced. In order to stimulate and facilitate local and international investment in renewable energy in the country, the Government of Namibia introduced net-metering rules for installations that total up to 500 kW for all renewable energy technologies. Feed-in tariffs (FITs) on renewable energy were also introduced for projects that are between 500 kW and 5 MW in capacity, including solar power, biomass and wind.[21]

In addition to these policies, the Government of Namibia introduced the Solar Revolving Fund (SRF) in 1996 through the MME as part of the OGEMP. This fund offers subsidised loans to the citizens of Namibia at a fixed interest rate of 5 per cent per annum for five years. Through the SRF, photovoltaic pumps, solar home systems, solar water heaters and energy-efficient stoves are financed.[22]

Though there is no targeted support for hydropower, a number of funding opportunities by African institutions are being considered by the Government of Namibia to support renewable energy projects in general, including hydropower, such as the African Development Bank's Clean Energy Investment Framework for Africa, the Sustainable Energy Fund for Africa and the African Renewable Energy Fund.[21]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

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

- The Electricity Act (2007);
- The Water Resources Management Act (2013);
- The S.W.A Water and Electricity Corporation Act (1980).

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

In Namibia, SHP development has been hindered by:

- High upfront capital costs exacerbated by high credit costs;
- Exchange rate fluctuations affect funding as the Namibian Dollar (NAD) is pegged by the South African Rand, which is subject to fluctuations affecting Namibia. As tariffs are set in NAD and foreign investment is in foreign currency, the devaluation of the NAD renders many projects costly;
- Insufficient government funding;
- Scarce inland water resources, as most of the important water resources are shared with neighbouring countries;
- Climate change is expected to exacerbate natural climate variability, creating more unpredictability of the hydrological regime;
- The legislation and policy in relation to SHP are unclear and need to be developed;
- Indigenous populations have concerns over displacement and other effects hydropower plant construction can have on their way of life.[5,21,23]

On the other hand, SHP development in Namibia is encouraged by:

- Government's interest in the exploitation of natural resources (solar, wind, thermal power) demonstrates an openness to maximizing the use of domestic resources, which could eventually include SHP;
- Government's interest in the development of renewable energy;
- National strategy aimed at making Namibia a hub for international investors in the energy sector;
- Trend towards the decentralization of the electricity sector that attracts local and international actors who can produce, transmit and supply electricity;
- Positive policy on renewable energy including renewable energy funds and FITs.

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South Africa

Wim Jonker Klunne, Hydro4Africa; and Bohuslav Barta, Energy and Water Resources Engineering Consultant

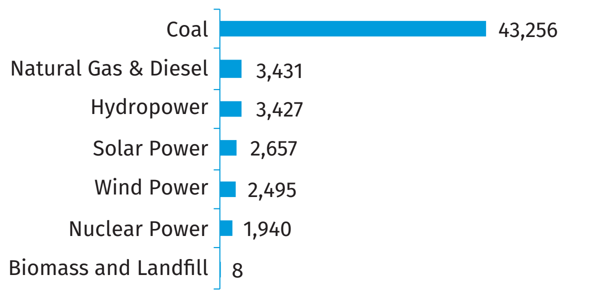
KEY FACTS

Population	59,620,000 (2020)[1]
Area	1,219,602 km^2[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 approximately 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]
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 winter, night temperatures can drop to the freezing point.[2]
Climate Change	South Africa is already experiencing significant impacts of climate change, particularly as a result of increased temperatures and rainfall variability. Since 1990, the rate of increase of the national average temperature has been more than double that of global temperature increases in the same period. This increase is more pronounced for the western parts and the north-east of the country. There is evidence that extreme weather events in South Africa are increasing, with heat wave conditions found to be more frequent, dry spell durations lengthening slightly and rainfall intensity increasing.[3]
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 Cape. 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. During the 2020/2021 fiscal year, a total of 214,926 GWh of electricity was generated. Of this total, 13,526 GWh (6 per cent) was generated by independent power producers (IPPs) and the rest by plants operated by the public utility ESKOM, including coal-fired power plants producing 183,553 GWh (85 per cent), nuclear power producing 9,903 GWh (5 per cent), large hydropower producing 6,182 GWh (3 per cent), open-cycle gas turbines producing 1,457 GWh (1 per cent) and wind power producing 305 GWh (less than 1 per cent) (Figure 1). Electricity imports in 2020/2021 stood at 8,812 GWh.[4]

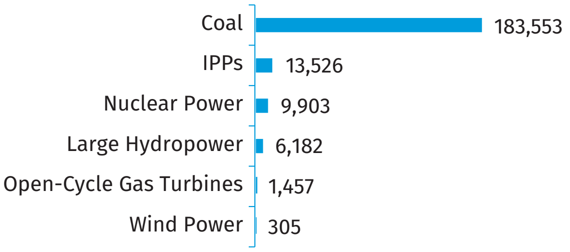
Figure 1. **Annual Electricity Generation by Source in South Africa in 2020/2021 (GWh)**



Source: ESKOM[4]

In 2021, the total installed capacity of South Africa was 57,214 MW, of which 43,256 MW (76 per cent) was represented by coal power plants, 3,431 MW (6 per cent) by natural gas and diesel power plants, 3,427 MW (6 per cent) by hydropower plants, 2,657 MW (5 per cent) by solar power plants, 2,495 MW (4 per cent) by wind power plants, 1,940 MW (3 per cent) by nuclear power plants and 8 MW (less than 0.1 per cent) by other sources including biomass and landfills (Figure 2). Approximately 89 per cent of total installed capacity was owned by ESKOM and the remaining 11 per cent was owned by Independent Power Producers (IPPs) and municipalities.[4]

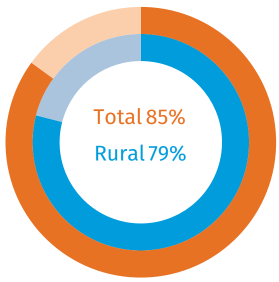
Figure 2. **Installed Electricity Capacity by Source in South Africa in 2021 (MW)**



Source: ESKOM[4]

Access to electricity across South Africa reached 85 per cent in 2019 (Figure 3). However, access to electricity in rural areas was only 79 per cent the same year and has been experiencing a decline since reaching nearly 84 per cent in 2014.[5]

Figure 3. **Electrification Rate in South Africa in 2019 (%)**



Source: World Bank[5]

The institutional framework of the electricity sector in South Africa includes the Department of Mineral Resources and Energy (DMRE) (previously Department of Energy) and the National Energy Regulator of South Africa (NERSA). The DMRE 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.[6] 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.[7] The South African National Energy Development Institute (SANEDI), carries out research and development activities to promote green energy technologies and energy efficiency.[8]

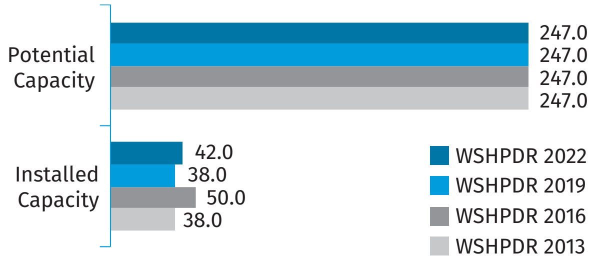
The electricity prices in South Africa depend on the supplier (ESKOM or municipality), the quantity of electricity used, the period (time or season) when the electricity is used, the volume of the supply, the geographic location of the customer, the voltage at which electricity is supplied and the cost of connecting to the supply. In 2021, average electricity prices rose to ZAR 1.349 ZAR/kWh (0.088 USD/kWh), an increase of nearly 16 per cent from 1.167 ZAR/kWh (0.076 USD/kWh) the previous year.[9,10]

SMALL HYDROPOWER SECTOR OVERVIEW

The Renewable Energy Independent Power Producers Procurement Programme (REIPPPP) is the main vehicle for the implementation of renewable energy technologies in South Africa, including small hydropower (SHP). During the first three bidding windows of the REIPPPP process, the maximum size of SHP plants was set at 10 MW. However, in the Request for Qualifications and Proposals for the third bidding window in June 2014, a new capacity limit of 40 MW was introduced for SHP.[11] A the same time, the draft Policy on Sustainable Hydropower Generation by the Department of Water and Sanitation (DWS) 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 current official definition of SHP in the country. However, for the purpose of comparison with the previous edition, this chapter will use data on hydropower up to 10 MW.

In 2021, the installed capacity of SHP up to 10 MW in South Africa stood at 42 MW, while potential was estimated at 247 MW.[13,14] Compared to the data cited in the *World Small Hydropower Development Report (WSHPDR) 2019*, potential capacity remained unchanged, while installed capacity increased by 1.8 per cent (Figure 4). The increase in installed capacity is due to one new SHP plant being commissioned in early 2021 on the As River.[13,15]

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



Sources: Jonker Klunne & Barta,[13] Barta,[14] *WSHPDR 2019*,[15] *WSHPDR 2013*,[16] *WSHPDR 2016*[17]

Note: Data are for SHP up to 10 MW.

Although not documented to a great detail, historically SHP 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 SHP and also smaller towns started local distribution of electricity through isolated grids powered by SHP plants. However, with the expansion of the national electricity grid and the cheap, coal-generated power supplied through the grid, large numbers of SHP plants 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.[18] Between 1917 and the mid-1950s, some 150 pico- to mini-hydropower plants were installed in South Africa, with a few surviving plants currently being refurbished.

After approximately 30 years of neglecting the hydropower potential of the country, the first new SHP plant was commissioned in 2009 in the Sol Plaatje Municipality in the Free State province. Since then, 13 other hydropower plants have been developed in the country.[19,20] A list of currently operational SHP plants is displayed in Table 1.

Table 1. **List of Operational Small Hydropower Plants in South Africa**

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Plant type*	*Operator*	*Launch year*
Kruisvallei	As River	4.700	N/A	Run-of-river	Red Rocket EPC	2021
KwaMadiba	Thina River	0.050	48	Run-of-river	Rural Local Council	2020
Doornkloof Reservoir	Tshwane City	0.009	N/A	Storage regulated, in-conduit	Tshwane Metropolitan Council	2020
Leliefontein	Drakenstein	0.555	N/A	Storage regulated, in-conduit PaT*	Drakenstein Municipality	2018
Cradle Moon Resort	Crocodile River	0.040	7	Run-of-river	Private	2018
Annlin Reservoir	Pretoria	0.150	N/A	Storage regulated, in-conduit PaT*	Tshwane Metropolitan Council	2017
Stortemelk	As River	4.400	14	Run-of-river	Renewable Energy Holdings	2016
L'Ormarins	Waterfall River	2.300	300	Run-of-river	Wine Estate Franschoek	2016
Neusberg	Kakamas	10.000	15.3	Run-of-river	Kakamas Hydro Electric Power	2015
Bloem Water Offices	Bloemfontein	0.096	N/A	Storage regulated, in-conduit	Bloem Water Board	2015
Pierre van Ryneveld Conduit	Pretoria	0.015	N/A	Storage regulated, in-conduit	Tshwane Metropolitan Council	2015
Badplaas Resort	Badplaas	0.150	10	Run-of-river	MBB Consulting	2013
Murludi Farm	Tulbagh	0.044	120	Run-of-river	Private	2013
Merino	As River	4.000	14	Run-of-river	Renewable Energy Holdings	2012
Mooi River Hydro	Mooi River	0.320	30	Run-of-river	Kruisfontein Farming Hydro	2012
Sol Plaatje	Liebenbergsvlei	3.000	11	Run-of-river	Renewable Energy Holdings	2009
Friedenheim	Crocodile River	3.600	62	Run-of-river	Friedenheim Irrigation Board	1987
Ncora	Tsomo River	2.400	40	Storage regulated	ESKOM	1983
Mtata First Falls	Umtata River	6.000	27.3	Storage regulated	ESKOM	1975
Steenbras Water Treatment Works	Steenbras Lower Reservoir	0.179	N/A	Storage regulated, in-conduit	Cape Town City Council	1946/1997

Source: Jonker Klunne & Barta,[13] Barta[14]

Note: *pumps as turbines

The South African Renewable Energy Database, as developed by the Council for Scientific and Industrial Research (CSIR), ESKOM and the Department of Minerals and Energy, investigated the available renewable energy resources in the country, including the potential for hydropower.[21] As a follow-up, the resources available for the Eastern Cape region were detailed as part of a 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.[22]

The 2002 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.[23] A later 2011 publication gave new insights into the potential of SHP 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]

SHP 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 SHP 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.[24] 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.[20] 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.[20] Bethlehem Hydro Pty Ltd owns two SHP 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.[20] 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 Kruisvallei SHP plant (4.7 MW) is constructed on the same water source and saw the start of commercial operation in February 2021.

The Neusberg plant of Kakamas Hydro Electric Power is the first run-of-river SHP plant 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.[25,26] The construction of the plant began in June 2013 and its operation began in 2015.[27] The Stortemelk hydropower plant 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.[28]

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 SHP capacity is less than the estimated potential and might therefore limit SHP development. The future for SHP 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 indicated an intention to submit hydropower projects for the fifth and sixth bidding windows. These included some larger plants along the Orange River and in the Eastern Cape Province. 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, for example, the 44 kW Murludi SHP plant and the 2.3 MW L’Ormarins SHP plant.[20] Development of small-scale plants are expected to grow based on the foreseen raise in electricity prices and decreased reliability of the grid. The development of SHP potential can be realized if the Government fully recognizes and adheres to the public-private partnership (PPP) implementation process in developing the renewable energy resources.[12]

Recent years have seen efforts to utilize existing water infrastructure for SHP development. For example, the water utility Rand Water has some 15 MW of SHP investigated at its four pressure break stations. Buffalo City has a significant hydropower potential, as assessed in 2013, at its water supply and sanitation infrastructure.[29] However, none of the investigated sites have been developed so far. In 2015, 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.[30] Most recently, a 9 kW conduit “otter” hydropower plant has been installed by the City of Tshwane at the Doornkloof reservoir. Yet another recent project is the Kwa Madiba (50 kW) community plant on the Thina River in the Eastern Cape Province, developed as community-managed rural electrification project .[31,32]

The actual installed SHP capacity of South Africa is substantially larger than can be reliably assessed. The primary reason for this is the large number of privately-owned SHP plants operating on private property and disconnected from both the national and local grids. These plants are often associated with mines and their collective installed capacity is estimated at approximately 80 MW. In some cases, hydropower units are also used to provide mechanical power in support of mining operations, rather than electricity generation. In most cases, the technical specifications of these plants and their operational status cannot be confirmed and they are thus excluded from the SHP total.[13]

While many additional SHP projects have been considered, there are currently only two in advanced stages of planning, at Mpompomo Falls and Bivane. In both cases, an environmental impact assessment (EIA) has been carried out.[14] Additional details on the two projects are provided in Table 2.

Table 2. **List of Ongoing Small Hydropower Projects in South Africa**

Name	*Loca-tion*	*Capacity (MW)*	*Head (m)*	*Plant type*	*Developer*	*Devel-opment stage*
Mpom-pomo Falls	Bar-berton	2.0	N/A	Run-of-river	Rosatom/ Ganz Engi-neering Blue World Power Energy and Resourc-es	EIA com-pleted
Bivane	Vry-heid	2.7	53	Storage	NuPlanet	EIA com-pleted

Source: Jonker Klunne & Barta,[13] Jonker Klunne[20]

Note: Data as of 2021.

Besides the operational plants, 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, 20] The Hydro4Africa database includes over 20 previously operational sites that have been abandoned or fallen into disrepair, in addition to 60 sites identified as suitable for potential development.[21] A short list of sites suitable for refurbishment is provided in Table 3.

Table 3. **List of Selected Potential Small Hydropower Sites in South Africa**

Name	*Location*	*Potential capacity (MW)*	*Head (m)*	*Type of site*
Buffelsfontein	Klerks-dorp	3.83	1,463	Refurbish-ment
Belvedere	Blyde River	2.12	58	Refurbish-ment
Ceres	Ceres	1.00	140	Refurbish-ment
Parys	Vaal River	0.80	10	Refurbish-ment
Bakenkop	Piet Retief	0.67	50	Refurbish-ment

Source: Barta,[14] Jonker Klunne[20]

Note: Data as of 2021.

The SHP 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.[33,34] Recent research conducted in the sphere of conduit hydropower technology application in South Africa investigated and proposed a generic method of evaluating hydropower potential in water supply infrastructure.[35] The potable water distribution system, where the mechanical energy of excess water pressure can be converted into electric energy, has been investigated in the City of Polokwane.[36] Under the SA-LED programme by the United States Agency for International Development (USAID), the !Kheis Local Municipality and the eThekwini Metropolitan Municipality have been supported in developing their hydropower resources.[37,38]

RENEWABLE ENERGY POLICY

South Africa has a full suite of policies in place regulating 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.[8]

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. The policy-adjusted development plan approved by the Cabinet set a target of 17.8 GW of total installed capacity for renewable energy by 2030. The main source of hydropower, as per the IRP2010, will come from imported electricity (approximately 2.6 GW by 2030), while local, small-scale hydropower and landfill gas-based electricity share an allocation of 125 MW.[39] In October 2019, an updated IRP was approved by the Cabinet. This IRP2019 sees an increased allocation of installed capacity for renewable energy, in particular wind and solar power, with a target of 8,288 MW of total installed capacity for wind power and 17,742 MW for solar power by 2030. However, the only hydropower allocation refers to imported electricity from the Inga3 hydropower plant in the Democratic Republic of the Congo.[40]

The energy mix scenario of the IRP is implemented through the REIPPPP, which was launched by the Department of Energy in 2011, switching from the feed-in tariff system that had been created in 2009. In the context of South Africa, renewable energy is very competitive and at the current stage does not require additional financial incentivization, with independent renewable energy operators being able to sell electricity to consumers at substantially lower prices than those of ESKOM.[13] The first three bidding windows of this programme were procured by 2015, after which the signing of the PPAs for the windows 3.5 and 4 was stalled until early 2018, causing a decrease in the interest in the renewable energy sector of the country, including from foreign investors. The signing of 26 outstanding PPAs in April 2018 brought new hope for renewable energy development in the country. In October 2021 the winning bids for bidding window 5 were announced, but did not include any hydropower projects.[41,42]

The REIPPPP process has initiated substantial activity in the hydropower sector. In total, over 19 MW of installed hydropower capacity has been procured from three hydropower plants (Table 4).[41]

Table 4. **Hydropower Capacity Procured under the REIPPPP**

Bidding window	*Hydropower plants*	*Capacity (MW)*
1	None	-
2	Stortemelk Power Plant	4.4
	Neusberg Hydropower Project	10
3	None	-
3.5	None (this window was solar CSP only)	-
4	Kruisvallei Hydropower	4.7
5	None	-
	Total	**19.1**

Source: Smit,[41] Smith[42]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

The effects of climate change on water resources is expected to be highly variable, with changes to average annual runoff by 2050 predicted to range between -13 per cent and +48 per cent. While this suggests the median impact scenario will generate a moderate increase in runoff on the national scale, regions may be unevenly affected, with the Western Cape region expected to experience a decline in average annual runoff of 13 per cent by 2050, while areas with a projected increase in runoff, such as the east coast, are at risk of flooding. The well-developed national water distribution system is expected to play a major role in mitigating the regional shifts in water supply.[43] Regionally, increased unpredictability in runoff is expected to create disruptions to hydropower generation in neighbouring countries, on which South Africa partially depends for its own electricity needs.[44] Potentially, these factors could encourage further development in South Africa of SHP that is integrated into the national water distribution grid, as a means of both utilizing the domestic water transfers for generation and building additional resilience against expected disruptions to electricity imports.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The constraints hampering more extensive development of SHP in South Africa include:

- Lack of relevant legislation slowing hydropower development at non-powered dams;
- Lengthy and expensive process for a successful EIA;
- The Water Use Permit (as per National Water Act/No. 36 of 1998) is sometimes difficult to obtain;
- Difficulties obtaining an acceptable PPA;
- Difficulties obtaining permission for access to, or crossing of, 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 SHP projects.

Factors enabling SHP development in South Africa include:

- A well-established bidding vehicle for renewable energy projects (REIPPPP), in 2022 entering its sixth successive period of activity;
- Extensive research carried out in-country on implementing SHP solutions on existing infrastructure, including water distribution and transfer systems;
- A significant number of assessed potential sites for SHP projects, as well as previously decommissioned plants in need of refurbishment.

With regard to the above constraints, the developers interested in installing SHP 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 PPP principles. All in all, it is expected that SHP can play a small but important role in the future energy mix of the country. The creation of a representative body (e.g., the country or regional SHP Association) would enable potential hydropower developers in the negotiation and technology implementation processes.

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Contributing organizations

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gef

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