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ON SMALL HYDROPOWER

World Small Hydropower Development Report 2022

Southern Asia

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Southern Asia

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Countries: Afghanistan, Bangladesh, Bhutan, India, Iran, Nepal, Pakistan, Sri Lanka

INTRODUCTION TO THE REGION

The electricity sectors of the countries in Southern Asia reflect the scale of their economies. India is by far the largest power producer in the region and one of the largest in the world, with a diversified electricity sector featuring significant investment in all major energy sources. By contrast, the electricity sectors of Nepal, Bhutan and Afghanistan are comparatively small, with Afghanistan being one of the least electricity-secure countries in the world. Nuclear power is a key energy source for several regional countries, including India, Pakistan and Iran. In Afghanistan, Bhutan and Sri Lanka, electricity generation is dominated by state-run companies, while in Bangladesh, India and Nepal, public and private companies account for roughly equal shares of generation.

Owing to the topography of Southern Asia, which includes the highest mountain ranges in the world, glaciers and extensive river valleys, the region is well-supplied with water resources appropriate for hydropower development. Hydropower accounts for nearly 100 per cent of the electricity generation in Bhutan and Nepal and plays a major role in the electricity sectors of every other country in the region with the exception of Bangladesh, where the development of hydropower is complicated by the slow-moving and meandering character of rivers.

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

Table 1. **Overview of Southern Asia**

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)
Afghanistan	33	98	97	641	1,031	333	881
Bangladesh	165	96	95	20,817	72,320	230	655
Bhutan	1	100	100	2,343	8,877	2,334	8,876
India	1,353	86	N/A	382,151	1,610,968	50,996	167,029
Iran	83	99	N/A	85,155	334,445	12,088	30,375
Nepal	31	90	N/A	1,333	6,012	1,278	N/A
Pakistan	215	74	N/A	38,719	134,746	9,861	38,988
Sri Lanka	22	100	100	4,531	16,762	1,824	4,812
Total	-	-	-	**535,690**	-	**78,944**	-

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 Asia varies across countries, with Afghanistan, Bhutan, India and Nepal defining SHP as hydropower plants up to 25 MW, and Iran and Sri Lanka adhering to the up to 10 MW definition. In Pakistan, the up to 25 MW definition as well as the up to 50 MW definition are applied by different pieces of legislation. No official definition of SHP exists in Bangladesh.

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

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

Country	Local SHP definition	Installed capacity (local def.)	Potential capacity (local def.)	Installed capacity (≤10 MW)	Potential capacity (≤10 MW)
Afghanistan	Up to 25 MW	N/A	N/A	83.2	1,200.0
Bangladesh	N/A	0.0	N/A	0.0	60.0
Bhutan	Up to 25 MW	32.4	23,296.0	8.4	8.9
India	Up to 25 MW	4,787.0	21,134.0	N/A	N/A
Iran	Up to 10 MW	19.5	90.8	19.5	90.8
Nepal	Up to 25 MW	662.5	4,000.0	N/A	N/A
Pakistan	Up to 50 MW	445.0	3,190.0	N/A	N/A
Sri Lanka	Up to 10 MW	424.6	873.0	424.6	873.0
Total	-	-	-	**535.7**	**2,232.7**

Source: *WSHPDR 2022*[1]

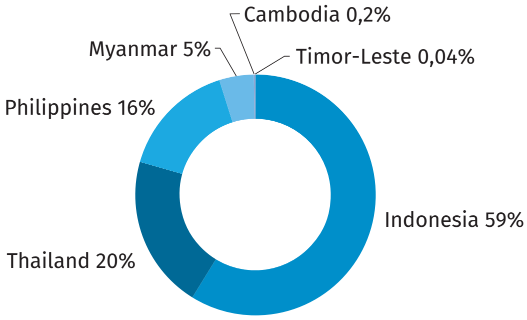
Note: *The up to 25 MW definition is also used.

India, Nepal, Pakistan and Sri Lanka all have robust SHP sectors, with SHP up to 25 MW accounting for approximately half of the total installed capacity of Nepal. The SHP sectors in these countries are additionally a major conduit for international cooperation projects. Sri Lanka has exported its considerable technical expertise in SHP to other parts of Asia as well as certain countries in Africa, while state-run agencies in Pakistan are involved in joint projects on hydropower promotion with China. In India and Nepal, the SHP sector is an important platform for private investments in energy development.

The installed capacity of SHP up to 10 MW in Southern Asia is 535.7 MW, while the potential capacity is estimated at 2,232.7 MW. Relative to the *World Small Hydropower Development Report (WSHPDR) 2019*, the total installed capacity of SHP up to 10 MW in Southern Asia has decreased by 23 per cent while the potential capacity decreased by nearly 47 per cent, mainly due to the lack of reliable and current data for Nepal on SHP up to 10 MW. In recent years, SHP development has been most active in India, Sri Lanka and Nepal, and moderate in Pakistan. By contrast, the SHP sectors of Bhutan and Afghanistan are significantly smaller, despite a considerable assessed SHP potential, and new projects have mostly consisted of micro- and mini-hydropower plants that contribute relatively little to the electricity capacities of these two countries. Little potential for SHP development has been identified in Iran and Bangladesh.

The national share of regional installed capacity for SHP up to 10 MW 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.

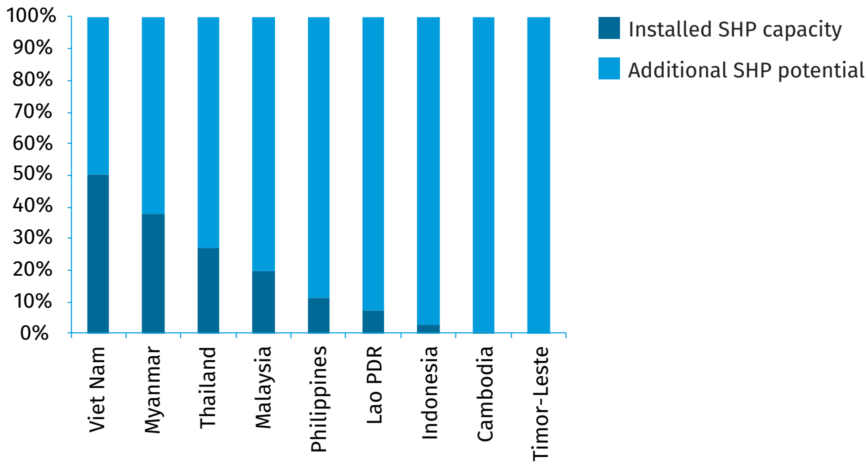
Figure 1. **Share of Regional Installed Capacity of Small Hydropower up to 10 MW by Country in Southern Asia (%)**



Source: *WSHPDR 2022*[1]

Note: India, Nepal and Pakistan not included due to lack of data on SHP up to 10 MW; Bangladesh not included due to lack of installed capacity for SHP up to 10 MW.

Figure 2. **Utilized Small Hydropower Potential by Country in Southern Asia (%)**



Source: *WSHPDR 2022*[1]

Note: For SHP up to 25 MW in the case of India, Nepal and Bhutan; for SHP up to 10 MW in the case of Sri Lanka, Iran, Afghanistan and Bangladesh; for SHP up to 50 MW in the case of Pakistan.

In **Afghanistan**, the total installed capacity of SHP up to 25 MW was estimated at 83.2 MW as of 2022, while potential capacity is estimated at 1,200 MW, suggesting that approximately 7 per cent has been developed. One new major SHP plant was commissioned in 2021, with another project nearing completion. However, only SHP up to 3 MW is classified as renewable energy under existing legislation. Most SHP development in Afghanistan in recent years has taken the form of mini- and micro-hydropower projects installed on isolated grids and funded by various support programmes, with an estimated 5,000 of such projects in different parts of the country.

There is no identified operational SHP capacity in **Bangladesh** as of 2022. The existence of several micro-scale SHP plants has been attested to in previous years, but they are no longer considered operational. The potential capacity for SHP up to 10 MW is estimated at 60 MW, with much of this potential concentrated in the hilly Chittagong region. Several recent studies have been carried out by national and international entities that identified a wide range of potential sites for new SHP construction as well as refurbishment of previously operational plants.

The total installed SHP capacity of **Bhutan** for SHP up to 25 MW was 32.4 MW in 2021, provided by 25 plants. With a single 24 MW plant providing most of this capacity. The total installed capacity for SHP up to 10 MW was 8.4 MW. Potential capacity for SHP up to 25 MW was estimated at 23,296 MW in 2017, indicating that significantly less than 1 per cent has been developed. There are no detailed data on the potential capacity for SHP up to 10 MW, but an estimate of 8.9 MW can be made on the basis of installed capacity and two additional projects under consideration as of 2021 with a total potential capacity of 0.5 MW. The overall installed SHP capacity of the country has changed little over the last decade, although several micro-scale plants have been commissioned. Several SHP projects with a total capacity of 83 MW are in the pipeline. Overall, existing plans for the development of hydropower resources in the country are focused on medium and large hydropower.

The total installed capacity of SHP up to 25 MW in **India** was 4,787 MW in 2021, while potential SHP capacity in the country is estimated at 21,134 MW, indicating that 22 per cent has been developed. The degree of SHP development varies considerably across different states, with Karnataka and Himachal Pradesh leading the country in both installed capacity and identified SHP potential. The SHP sector in India is actively expanding and a number of new SHP plants were commissioned in 2020. The Ministry of New and Renewable Energy is spearheading SHP development through support for SHP research and documentation of standards, while construction of new plants has been primarily carried out by the private sector.

The total installed capacity of **Iran** for SHP up to 10 MW was 19.5 MW as of 2021. There is a lack of clear data on potential SHP capacity in the country, but based on the sum of capacities for existing plants, planned project and identified potential sites, potential SHP capacity is estimated at 90.8 MW, indicating that over 21 per cent has been developed. Estimates of potential SHP capacity in the country have decreased following the cancellation of several planned projects in 2019. Little SHP development has taken place in the last decade, with the most recent utility-scale SHP plant commissioned in 2011.

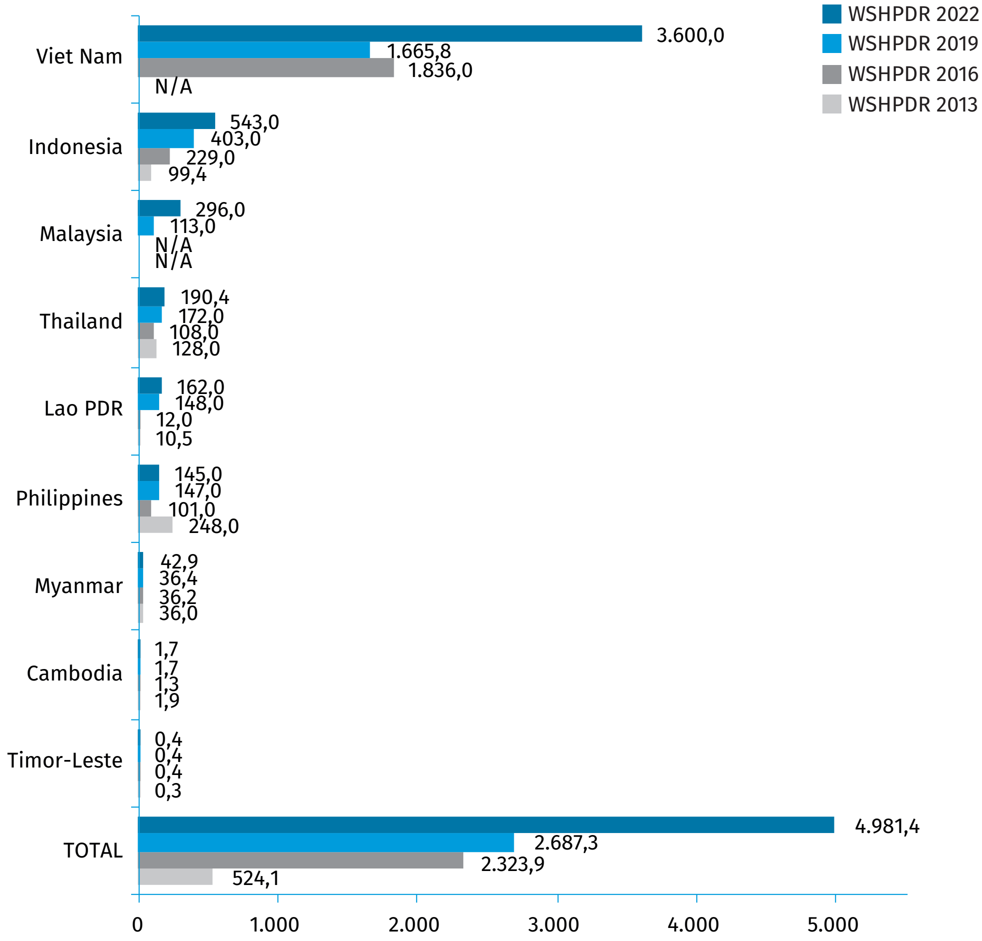
The total installed capacity in **Nepal** for SHP up to 25 MW was 662.5 MW in 2021, with SHP up to 10 MW accounting for the bulk of this capacity. Potential capacity for SHP up to 25 MW is estimated at 4,000 MW, indicating that approximately 17 per cent has been developed. In addition to utility-scale SHP plants, some 3,000 micro-hydropower plants operate in the country, providing power to rural and isolated areas. Development in the SHP sector is actively ongoing. As of 2021, a large number of prospective SHP projects totalling several thousand megawatts have either been granted generation licences or licences in preparation for feasibility studies.

The total installed capacity in **Pakistan** for SHP up to 50 MW was 445 MW as of 2020, while potential capacity is estimated at 3,190 MW, indicating that approximately 14 per cent has been developed. The Gilgit-Baltistan province hosts the largest concentration of SHP in the country and also contains the greatest estimated SHP potential. Development of SHP in Pakistan is pursued by a variety of public, private and international actors, including the Alternative Energy Development Board and the Pakistan Council of Renewable Energy Technologies. Joint Pakistan–China research centres for SHP technologies have been established in Islamabad and Peshawar and international funding for SHP projects has been provided by the Asian Development Bank, Swiss Agency for Development and Cooperation and the Aga Khan Foundation. At least five SHP projects were under construction as of 2021.

The total installed capacity of SHP up to 10 MW in **Sri Lanka** was 424.6 MW in 2019, provided by 205 grid-connected SHP plants. The potential capacity for SHP up to 10 MW in the country is estimated at 873 MW, indicating that approximately 49 per cent has been developed. The Ratnapura and Nuwara Eliya districts lead the country in installed SHP capacity. SHP development is very active in the country with over 20 new plants launched in 2018–2019, although procurement bottlenecks have led to a backlog of planned projects with a cumulative capacity of 100 MW, and no new power purchase agreements have been signed with developers since 2015. SHP developers from Sri Lanka have been expanding their reach internationally and pursuing projects in other parts of Asia as well as in African countries.

Changes in the installed SHP capacities of countries in the 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 from *WSHPDR 2013* to *WSHPDR 2022* by Country in Southern Asia (MW)**



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

Note: For SHP up to 25 MW in the case of India, Nepal and Bhutan; for SHP up to 10 MW in the case of Sri Lanka, Iran, Afghanistan and Bangladesh; for SHP up to 50 MW in the case of Pakistan.

Climate Change and Small Hydropower

Precipitation patterns in the region have already been affected by climate change, but not consistently. The Himalayan region is characterized by heavy monsoon precipitation during summers and dry winters, and hydropower projects face risks due to Glacier Lake Outburst Floods (GLOFs). Most climate change models project a strengthened monsoon, resulting in an overall increase in runoff. Bhutan expects the most significant changes in streamflow after the mid-21st century due to increasing temperatures and higher glacier melt rates. Regions with low glacier coverage are expected to see reduced streamflow. Moreover, the impact on SHP generation and development is expected to have wide seasonal variation. Adaptive measures will be required in catchments utilized by SHP plants in order to reduce the adverse effects of seasonal flow variability. Moreover, floods and heavy sediment inflow should be considered in the operational and maintenance costs of SHP plants to avoid structural damage.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The prospects for further SHP development in **Afghanistan** are unclear, although the country possesses considerable untapped SHP potential. While most development in recent years has been supported by international donors, there is a lack of local technical capacity and private sector investment in SHP as well as a lack of means on the part of the local population to pay for electricity. In the near term, development of SHP in the Afghanistan is complicated by the decreased presence of international financing in the country after 2021.

SHP development in **Bangladesh** is complicated by the hydrological conditions featuring large, slow-moving rivers with low head, shifting riverbanks and frequent flooding, as well as by the country's high population density limiting the availability of land. A large number of potential sites have been identified and assessed in recent studies, but it is unclear how many are economically feasible due to the relatively high cost of construction.

While **Bhutan** possesses very significant hydropower resources, plans for their development have focused on large and medium hydropower at the expense of SHP. Additionally, there is a lack of targeted support programmes for SHP. Prospects for the development of SHP in the country include their lower cost relative to larger projects and ability to be funded by domestic firms without extensive reliance on foreign capital.

The conditions for SHP development in **India** are favourable overall and include access to government subsidies, power purchase guarantees for SHP operators on the part of electricity distributors, dedicated government loans and a well-established base of both technical documentation on SHP and data on SHP potential, in addition to considerable local technical expertise. Obstacles to SHP development include a lengthy licensing process and opposition to SHP construction by local communities and environmental activists, which along with other factors has contributed to rising capital costs of construction and decreasing competitiveness of SHP in the country relative to other renewable energy sources.

As in Bhutan, hydropower development in **Iran** has mostly focused on large-scale projects. Owing to the hydrological regime across much of the country, hydropower development is typically feasible on watercourses that can host a significant reservoir, with smaller rivers running dry during parts of the year. Climate change has also had an outsized impact on the country's hydropower resources. At the same time, Iran does possess a legislative framework supportive of renewable energy development and SHP in particular, including feed-in tariffs.

In **Nepal**, support for SHP development exists in the form of established government power purchase rates for SHP projects as well as a range of tax exemptions. The country has access to considerable local expertise in SHP and substantial undeveloped SHP potential. Obstacles to development include insufficient demand for additional projects, lack of clarity and integration in the regulation and licensing of plants and problems with grid connections. Multiple environmental issues also hamper development in the SHP sector, including excessive sedimentation of rivers, weak geology of river banks and inconsistent stream flow.

Development of SHP in **Pakistan** is hindered by a complicated licensing process and a lack of coordination among the involved government institutions, high cost of SHP construction due to a lack of local sourcing for components and low demand for electricity in regions where SHP potential is greatest. However, these obstacles are counterbalanced by the commitment to further hydropower and SHP development on the part of the Government of Pakistan, expressed in several programmes promoting SHP development, which include preferential lending conditions and guaranteed upfront tariffs.

The main obstacles to further SHP development in **Sri Lanka** are procurement bottlenecks and a long list of back-logged projects, lack of recent data on remaining undeveloped SHP potential and an absence of effective environmental monitoring of SHP construction and operation contributing to increased public opposition to further SHP development. The country has considerable local expertise in the SHP sector and previous government policy had established high purchase prices for electricity from renewable energy sources. However, recent changes in policy and the 2022 economic crisis in the country make it difficult to predict future price dynamics for electricity from renewable energy.

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Islamic Republic of Afghanistan

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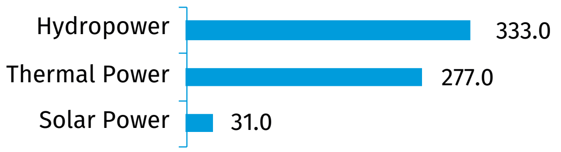
KEY FACTS

Population	32,890,171 (2020)[1]
Area	652,864 km^2 [1]
Topography	Afghanistan is a mountainous country, with mountains covering 63 per cent of the territory. The Hindu Kush Mountain Range splits the country from east to west. The average elevation is 1,100 metres above sea level, with 27 per cent of the country reaching an altitude of 2,500 metres. The highest point is Mount Noshaq at 7,485 metres, while the lowest point is the Amu Darya River at 258 metres.[2]
Climate	Afghanistan is located in the arid subtropics and has a semi-arid climate with cold winters and hot summers. The average temperature is 33 °C in June–August and 10 °C in December–February. The mountainous areas experience lower temperatures throughout the year, with winter temperatures being below 0 °C and summer temperatures being below 15 °C.[2]
Climate Change	Since the 1950s, the average annual temperature in Afghanistan increased by 1.8 °C. The most affected areas are in the south of the country, with an average temperature increase of 2.4 °C. The least affected regions are located in the east, with a temperature increase of 0.6 °C.[3]
Rain Pattern	Precipitation is most abundant in the winter, in the form of snow, and during the spring, in the form of rain. Annual precipitation averages 327 mm.[2] The wettest month is March and the driest month is September, with an average of 61.3 mm and 4.5 mm of precipitation observed over the 1991–2020 period, respectively.[4]
Hydrology	Afghanistan has five river basins: Kabul, Helmand, Harirud, Amu and Northern River. The Kabul River is the only river with a steady flow throughout the year, while most rivers turn to rivulets during dry seasons. Mountains form the backbone of the rivers in the country. The longest river, the Helmand, originates from the Central Hindu Kush Mountains. The Harirud River, flowing westwards and north-westwards to the border with Iran, is a key irrigation source in the Herat region.[5] Per capita water availability amounts to 2,775 m^3.[6]

ELECTRICITY SECTOR OVERVIEW

Electricity generation in Afghanistan in 2020 totalled 1,030.9 GWh, which was almost 20 per cent lower than in 2019. The main source of electricity generation in the country is hydropower, accounting for over 85 per cent of total generation in 2020. Thermal and solar power accounted for the remaining 12 per cent and 3 per cent, respectively (Figure 1).[1] A further 5,152 GWh was imported from Uzbekistan, Tajikistan, Iran and Turkmenistan. Thus, imported electricity accounted for over 80 per cent of the total electricity supply in 2020.[1] The limited domestic generation remains the key challenge for energy security and energy access in Afghanistan.

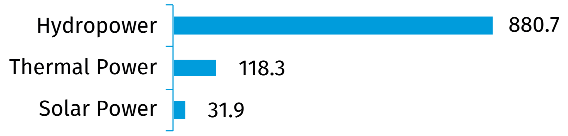
Figure 1. **Annual Electricity Generation by Source in Afghanistan in 2020 (GWh)**



Source: NSIA[1]

The total installed capacity of Afghanistan in 2020 stood at 641 MW. Hydropower accounted for 52 per cent of the total, thermal power for 43 per cent, while solar power accounted for 5 per cent (Figure 2).[7] The renewable energy potential in the country is estimated to exceed 300,000 MW, consisting of 222,849 MW of solar power potential, 66,726 MW of wind power potential, 23,310 MW of hydropower potential and 4,000 MW of biomass potential.[8]

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



Source: IRENA[7]

Afghanistan has one of the lowest per capita electricity consumption rates in the world, however, the demand has been growing in recent years. According to the statistics of the national power utility, Da Afghanistan Brishna Sherkat (DABS), electricity consumption in 2018, 2019 and 2020 totalled 6.0 TWh, 6.3 TWh and 7.1 TWh, respectively. This indicates an increase in per capita consumption from 178 kWh in 2013 to 216 kWh in 2020.[9] Electricity demand is projected to continue growing in the coming decades. To meet this growing demand, the Afghanistan Renewable Energy Policy set a target of adding 5,000–6,000 MW of new generation capacity by 2032. Of this total, 95 per cent was set to come from renewable energy sources, primarily hydropower and solar power.[10]

The percentage of population with access to electricity was 98 per cent in 2019, including 100 per cent in urban areas and 97 in rural areas.[11,12,13] A significant share of the population with access to electricity relies on off-grid systems. Although more recent data are not currently available, in 2017 it was reported that of the rural population, which accounted for 77 per cent of the total population that year, only 11 per cent had access to the national grid.[14]

Previously, under the Power Service Regulation Act of Afghanistan, the Ministry of Energy and Water (MEW) was responsible for policy making for the power sector of Afghanistan. However, since 2020, MEW has been split into two entities: the Afghanistan National Energy Regulatory Authority (NERA) and the Afghanistan National Water Regulatory Authority (NWRA).

The state-owned utility DABS and NERA are the main public organizations involved in the development of the country's energy sector. NERA is responsible for the regulation of the energy sector, while DABS is responsible for the management of electricity generation, transmission, distribution, trade and operation and management of electricity generating facilities across the country. Other key stakeholders in the energy sector include:

- Energy Steering Committee (ESC), which is the highest decision-making body in the energy sector;
- Ministry of Commerce (MoC), which oversees imports and exports;
- Afghanistan Renewable Energy Union (AREU), which represents the private sector in the renewable energy sector;
- Afghanistan National Standards Agency (ANSA);
- National Environmental Protection Agency (NEPA);
- International organizations (e.g., United Nations Development Programme (UNDP)), international financial institutions (e.g., Asian Development Bank (ADB)) and donor agencies (e.g., GIZ).[14]

Electricity prices vary depending on the region. On average, the price for electricity from the national grid ranges from 0.03 USD/kWh to 0.60 USD/kWh.[14] Electricity tariffs for electricity from the national grid are set by the national power utility DABS. Prices for electricity generated by independent small power producers are fixed and negotiated between producers and consumers. At the moment, there is no national regulator in place to regulate electricity prices in the country. However, it is expected that the newly established power regulatory authority NERA will be responsible for setting national tariffs.

SMALL HYDROPOWER SECTOR OVERVIEW

According to the Renewable Energy Policy of Afghanistan, small hydropower (SHP) is defined as hydropower plants with capacity of up to 25 MW, with a further classification into pico-, micro- and mini-hydropower (Table 1). Under the policy, only projects up to 3 MW are classified as renewable energy projects.[10] For the purposes of comparison with the previous editions of the *World Small Hydropower Development Report (WSHPDR)*, this chapter will follow the up to 10 MW definition of SHP.

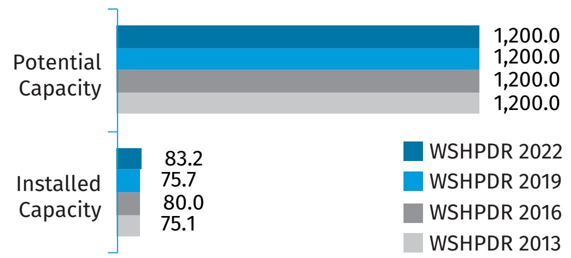
Table 1. **Classification of Small Hydropower in Afghanistan**

Category	Capacity
Pico	Below 2.5 kW
Micro	Below 250 kW
Mini	Below 2.5 MW
Small	Below 25 MW

Source: MEW[10]

The *WSHPDR 2019* reported that in 2016 the installed capacity of SHP plants in Afghanistan totalled 75.7 MW.[15] No new official statistics on total SHP installed capacity in the country have been made publicly available since then. However, it is known that one new SHP project was launched in 2021, the 7.5 MW Shorabak SHP plant (Table 2).[16] Also in 2021, the 9 MW Kamal Khan SHP plant was completed, however, as of the moment of writing of this chapter the powerhouse had not yet been installed due to financial issues and the plant was not in operation.[17] Thus, based on the available data, it can be estimated that the installed capacity of SHP plants up to 10 MW in the country was at least 83.2 MW in 2022. The SHP potential is estimated to be 1,200 MW and remains unchanged since the *WSHPDR 2019* (Figure 3).[18] The potential of mini- and micro-hydropower projects up to 1 MW in the country is estimated at 65.9 MW.[19]

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



Source: *WSHPDR 2019*,[15] Anadolu Agency,[16] Akbar & Burhan,[18] *WSHPDR 2013*,[20] *WSHPDR 2016*[21]

Table 2. **List of Selected Existing Small Hydropower Plants in Afghanistan**

Name	*Location*	*Capacity (MW)*	*Plant type*	*Launch year*
Shorabak	Kokcha River	7.50	Reservoir	2021
Assadabad	Kunar River	0.70	N/A	1983
Ghorband	Ghorband River	0.30	N/A	1975
Charekar	Ghorband River	2.40	N/A	1973
Pul-e-Khumri 2	Pulikhumri RIver	8.79	N/A	1962
Grishk	Helmand River	2.40	N/A	1957
Pul-e-Khumri	Pulikhumri RIver	4.12	N/A	1950
Jabul Seraj	Salang River	2.50	N/A	1920
Chaki Wardak	Logar River	3.30	Reservoir	N/A
Yakchew	Suhanda District	0.10	N/A	N/A
Farghamero	Jurm District	0.07	N/A	N/A
Shasht (Rehab)	Rokha District	0.07	N/A	N/A
Khondut	Makhan District	0.06	N/A	N/A
Maloma	Karukh District	0.06	N/A	N/A
Kohnadeh	Khenjan District	0.05	N/A	N/A
Dahan e sai and Etafaq	Shikh Ali District	0.04	N/A	N/A
Ewate	Warseje District	0.04	N/A	N/A
Pirghola	Balkhaa District	0.04	N/A	N/A
Sure Bouhondy	Lalsarjungle District	0.03	N/A	N/A

Source: Anadolu Agency,[16] Danish et al.,[22] MRRD[23]

It is reported that under various support programmes over 5,000 mini- and micro-hydropower plants have been developed in Afghanistan. These plants are located in remote areas, not yet connected to the national grid, and feed power into mini-grids. Mini-grid solutions have been preferred in remote areas where the cost of connecting to the national grid would be too high and, thus, have been a central element of SHP development in many parts of the country.[19]

SMALL HYDROPOWER AVAILABLE FOR INVESTMENT

A number of SHP projects have been recommended by the Government of Afghanistan for investment. Table 3 lists some of these projects. Additionally, some solar-hydropower hybrid projects are also available for investment.[24]

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

Name	*Location*	*Potential capacity (MW)*	*Type of site (new/ refurbishment)*
Spogmee	Badakhshan Province	2.5	New
Kuraan Wa Munjan	Badakhshan Province	1.5	New
Yanghi Qalaa	Takhar Province	1.0	New
Farkhar	Takhar Province	0.5	New
Namak Ab	Takhar Province	0.5	New

Source: Government of Afghanistan[24]

Note: Data as of 2016.

RENEWABLE ENERGY POLICY

The legal and policy documents developed by the Government of Afghanistan and pertaining to the topics of climate change, environment and energy include the following:

- Environment Law, 2007;
- Energy Sector Strategy, 2007;
- Fuel Consumption Regulations, 2010;
- Afghanistan Green Urban Transport Strategy, 2014;
- Afghanistan Energy Efficiency Code for Building, 2015;
- Renewable Energy Policy, 2015;
- Intended Nationally Determined Contribution (INDC) of Afghanistan, 2015;
- Power Services Regulation Act, 2015;
- Afghanistan National Peace and Development Framework, 2017;
- Renewable Energy Roadmap, 2017.

The Renewable Energy Policy of Afghanistan set the ambition of reaching a 95 per cent share of electricity generation from renewable energy sources by 2032.[10] According to the 2019 National Housing Policy, environmental sustainability and energy efficiency are key to the development of the country's housing sector.[25] The INDC of Afghanistan emphasizes electricity production from hydropower, solar power, wind power and biomass.[26] The Environment Law mandates that the National Environmental Protection Agency (NEPA) is responsible for the development and implementation of national environmental policies and strategies in relation to water, solid waste, pollution and natural habitat.[27] Moreover, for the first time Afghanistan recognized climate change as a serious threat to the country in the National Peace and Development Framework (2017–2021).[28]

COST OF SMALL HYDROPOWER DEVELOPMENT

The average cost of micro- and mini-hydropower projects developed in Afghanistan under support programmes is estimated at approximately 1,850 USD/kW.[19]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Hydropower plants, particularly small-scale and run-of-river ones, are particularly sensitive to variations in water flow. In Afghanistan, hydropower generation is prone to seasonal variability and declines significantly during seasonal drops in river flow. Under the scenario of reduced precipitation, it is projected that by 2050 hydropower production in the country will decrease significantly. While exact estimates for SHP plants are not available, the larger 52.5 MW Kajaki and 100 MW Naghlu hydropower plants are expected to have zero production at least once every 10 and 20 years, respectively.[19]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Given that micro-to-small hydropower is mostly used in the country's rural areas, barriers to SHP development in Afghanistan should be considered in the wider context of barriers to rural infrastructure and renewable energy expansion. The key barriers include:

- Lack of concessionary loans (with sovereign guarantees) for rural electrification projects;
- The need for greater involvement from major international actors for infrastructure development, environmental protection and private sector support;
- Lack of private sector investment in rural energy, despite the recent increase in the number of companies and entrepreneurs;
- Lack of presence from international financial institutions to support the private sector;
- Lack of essential data for the electricity sector;
- Most consumers are either unwilling or unable to pay the full cost of electricity supply, which results in cash-flow deficits, particularly for operators of isolated mini-grids;
- Overall instability in the country is a constraint to the timely implementation of the power sector strategy;
- Limited number of trained personnel capable of producing improved generation units from standard technical plans;
- Limited geographic coverage and operational synchronization of the grid;
- Significant gaps in the legal and regulatory framework;
- Lack of coordination among responsible agencies for the planning and management of renewable energy development, which often leads to long lead times.[15]

At the same time, a number of factors that can be considered as enablers for further SHP development in the country exists, including:
Long history of hydropower generation in the country;
Significant untapped SHP potential;
Central place of renewable energy, including hydropower, in the country's energy strategy.

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Bangladesh

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KEY FACTS

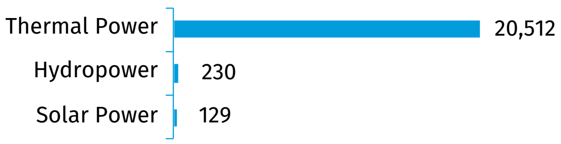
Population	164,689,383 (2020)[1]
Area	147,570 km^2[2]
Topography	Bangladesh is situated on the deltas of several large rivers flowing from the Himalayas and the topography of most parts of the country is extremely flat. Approximately 50 per cent of the country lies below 10 metres and 90 per cent below 110 metres above sea level. Hills cover approximately 10 per cent of the country's area. The highest peak in Bangladesh is Saka Haphong at 1,052 metres, located in the extreme south-eastern corner of the country.[3]
Climate	Bangladesh has a tropical monsoon climate characterized by wide seasonal variations in rainfall, high temperatures and high humidity. The average temperature varies between 11 °C and 20 °C in the winter months (December to February) and between 24 °C and 31 °C in the pre-monsoon summer months (March to May). Average humidity varies between 71 per cent in March and 86 per cent in July.[4]
Climate Change	Bangladesh has experienced a gradual increase in mean annual temperatures between 1961 and 2014, at a rate of approximately 0.06 °C every 10 years. Over the past few decades, the country has been experiencing warmer winters with significant increases in the minimal seasonal temperature, as well as hotter summers during the monsoon and pre-monsoon season. Minimum seasonal temperatures have increased by 0.45–0.52 °C, while maximum temperatures rose by 0.42–0.87 °C.[5]
Rain Pattern	The annual average rainfall is 2,666 mm. Rainfall varies from 1,500 mm in the north-west to approximately 4,400 mm in the north-east. More than 70 per cent of the total annual rainfall occurs in the monsoon from June to September, while 3 per cent occurs during the winter season.[6]
Hydrology	Most of Bangladesh lies in the delta formed by the convergence of the Ganges, Brahmaputra and Meghna Rivers and their tributaries. The country is crisscrossed by numerous rivers, streams and brooks, generally running north to south as they meet up with the Ganges to flow into the Bay of Bengal. In the dry season, the numerous tributaries that lace the terrain may be several kilometres wide as they near the Bay of Bengal, whereas at the height of the summer monsoon season they coalesce into an extremely broad expanse of silt-laden water. Most of the rivers of Bangladesh are in their old stage and changes in the position of riverbanks and channels are a common phenomenon.[7,8]

ELECTRICITY SECTOR OVERVIEW

The total installed electricity generating capacity in Bangladesh was 20,871 MW as of the end of 2021. Thermal power including gas, furnace oil, diesel and coal provided 20,512 MW (98 per cent) of the total, hydropower provided 230 MW (1 per cent) and large-scale solar power provided 129 MW (less than 1 per cent) (Figure 1).[9,10] Additional solar power capacity exists in the form of small-scale installations, both on- and off-grid, as well as minor capacities of other renewable energy sources (RES) including wind power and biomass.[11] Finally, a further 1,160 MW was available for power generation in 2021 through interconnections with India.[9,10]

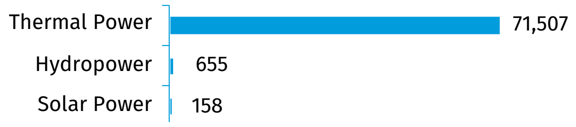
Generation of electricity during the 2020–2021 fiscal year reached 72,320 GWh, with thermal power providing 71,507 GWh (99 per cent) of the total, hydropower providing 655 GWh (less than 1 per cent) and other RES providing 158 GWh (less than 1 per cent) (Figure 2). Imports from India amounted to 8,103 GWh.[10]

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



Source: BPDB[9,10]

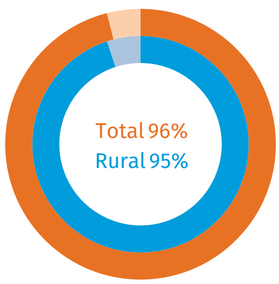
Figure 2. **Annual Electricity Generation by Source in Bangladesh in 2020–2021 (GWh)**



Source: BPDB[10]

Nationwide access to electricity in Bangladesh was approximately 96 per cent in 2020 and 95 per cent in rural areas (Figure 3).[12] Annual consumption of electricity in 2020–2021 amounted to 76,323 GWh, while transmission losses accounted for 2,330 GWh or approximately 3 per cent of available electricity.[10] Peak electricity demand in 2021 was 13,792 MW.[9]

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



Source: World Bank[12]

The ownership structure of the electricity generation sector of Bangladesh includes state-owned companies operating 57 plants accounting for 10,146 MW (49 per cent) of the total electricity capacity, private companies operating 88 plants of 9,481 MW (45 per cent) and one plant of 1,244 MW (6 per cent) operated as a joint venture between a state-owned company from Bangladesh and a Chinese state-owned company.[9] The transmission grid is operated by the Power Grid Company of Bangladesh Ltd. (PGCB) and as of 2021 included 950 kilometres of 400 kV lines, 3,658 kilometres of 230 kV lines and 8,228 kilometres of 132 kV lines. The Bangladesh Power Development Board (BPDB) purchases electricity from generation licensees and sells it to distribution licensees using the transmission network owned and operated by PGCB, for which PGCB is paid a wheeling charge. Distribution of electricity is carried out by six companies (including the BPDB itself).[10]

The development of the electricity sector of Bangladesh is guided by the Power System Master Plan (PSMP) 2016. Key targets of the plan include the enhancement of infrastructure for energy imports, efficient development of domestic fossil fuel resources, upgrades to the national power grid, accelerated development of RES and human capacity development. The most significant challenge to be addressed by ongoing development of the electricity sector in the country is rapidly increasing electricity demand, projected to reach approximately 52,000 MW by 2041. To meet rising demand, the Government of Bangladesh plans to expand domestic generating capacity, including increasing total RES capacity to 3,864 MW and constructing 7,000 MW of nuclear power, as well as achieving a cumulative total of 9,000 MW of interconnected cross-border power supply for electricity imports by 2041. While the Plan does not include targets for conventional hydropower development due to perceived social and environmental risk, the potential for the construction of pumped-storage power plants (PSPP) for the provision of ancillary services is recognized.[13,14]

The Bangladesh Energy Regulatory Commission (BERC) regulates electricity tariffs in Bangladesh based on the Power Pricing Framework (2004), with tariffs differing by consumer category, electricity consumption volume (for residential consumers) and time of day.[15] Electricity tariffs for low-voltage connections current as of February 2020 are displayed in Table 1.[16]

Table 1. **Electricity Tariffs for Low-Voltage Connections as of February 2020**

Consumer category	*Usage category*	*Tariff in BDT/kWh (USD/kWh)*
1. Residential	Lifeline (0 to 50)	3.75 (0.041)
	0 to 75	4.19 (0.046)
	76 to 200	5.72 (0.063)
	201 to 300	6.00 (0.066)
	301 to 400	6.34 (0.070)
	401 to 600	9.94 (0.109)
	> 600	11.46 (0.126)
2. Agricultural pumping		4.16 (0.046)
3. Small industries	Flat Rate	8.53 (0.094)
	Off-Peak Time	7.68 (0.084)
	Peak Time	10.24 (0.113)
4. Educational, religious, and charitable institutions and hospitals		6.02 (0.066)
5. Construction		12.00 (0.132)
6. Street lights and water pumps		7.70 (0.085)
7. Battery charging stations	Flat Rate	7.64 (0.084)
	Off-Peak Time	6.88 (0.076)
	Super Off-Peak	6.11 (0.067)
	Peak Time	9.55 (0.105)
8. Commercial & office	Flat Rate	10.30 (0.113)
	Off-Peak Time	9.27 (0.102)
	Peak Time	12.36 (0.136)
9. Temporary		16.00 (0.176)

Source: BERC[16]

SMALL HYDROPOWER SECTOR OVERVIEW

There is no official definition of small hydropower (SHP) in Bangladesh. For the purpose of the current chapter, the up to 10 MW definition of SHP will be used. As of 2022, there were no operational SHP plants in Bangladesh, while potential SHP capacity was estimated at approximately 60 MW.[13,17] Relative to the *World Small Hydropower Development Report (WSHPDR) 2019*, installed SHP capacity decreased 100 per cent due to a better understanding of the operational status of previously commissioned plants, while the estimate of potential capacity has increased marginally (less than 1 per cent) (Figure 3).[18]

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

Source: MPEMR,[13] Shahid,[17] *WSHPDR 2019*,[18] *WSHPDR 2013*,[19] *WSHPDR 2016*[20]

The first SHP plant in Bangladesh was installed for demonstration purposes in Bamerchara, Chittagong District, with a capacity of 10 kW. Another 10 kW plant was installed in Bandarban and a 50 kW SHP plant was constructed in Barkal Upazila, Rangamati District. However, these SHP plants are no longer operational.[17,21-,22,23] SHP potential in Bangladesh has been explored by different organizations over the last three decades. In 1981, the Bangladesh Water Development Board and BPDB jointly identified 19 prospective sites for SHP plants, while in 1984, a team of foreign consultants identified 12 potential sites for developing mini-hydropower plants with capacities between 4 kW and 616 kW. A 2021 country-wide study identified SHP potential on 232 rivers in Bangladesh. The hilly Chittagong region is considered to be one of the more promising locations for any future SHP development. In 2004, the Local Government Engineering Department (LGED) explored seven sites, mostly located in Chittagong, with capacities ranging between 3 kW and 30 kW and a total potential capacity of approximately 135 kW. Additionally, the Bangladesh Council of Scientific and Industrial Research (BCSIR) identified two sites in the Chittagong hill tract area with capacities of 5 kW and 15 kW.[21,22,23,24] Overall, the potential capacity of SHP in Bangladesh has been estimated at 60 MW.[13,25]

Potential sites for SHP development in Bangladesh include both previously operational plants that require repair or refurbishment as well as prospective new sites identified in earlier studies. A partial list of potential sites is provided in Table 2.

Table 2. **List of Selected Potential Small Hydropower Projects in Bangladesh**

Name	*Location*	*Potential capacity (MW)*	*Head (m)*	*Type of site (new/ refurbishment)*
Barkal Upazila	Rangamati	0.050	N/A	Refurbishment
Sealock Khal	Bandarban	0.030	N/A	New
Madhobkundu	Moulvibazar	0.015	10	New
Bamerchara	Chittagong	0.010	10	Refurbishment
Sailopropat	Bandarban	0.005	6	New

Source: Razan et al.,[21] Islam et al.[23]

RENEWABLE ENERGY POLICY

As a signatory of the United Nations Framework Convention of Climate Change (UNFCCC), Bangladesh committed to an unconditional reduction of greenhouse gas (GHG) emissions in the power sector of 5 per cent, as well as a conditional reduction of 18 per cent, by 2030.[26] Likewise, adaptation to climate change impacts and the promotion of RES feature prominently in the PSMP 2016. Promotion of RES development and energy efficiency in Bangladesh is undertaken by the Sustainable and Renewable Energy Development Authority (SREDA). The Energy Efficiency and Conservation Master Plan up to 2030 prepared by SREDA in 2015 aims to achieve a 15 per cent increase in energy efficiency by 2021 and a 20 per cent increase by 2030.[27]

The RES policy of Bangladesh was drafted in 2008, with the aim of identifying domestic RES and the potential for their development, as well as facilitating investment in RES projects. Key targets of the policy included increasing the contribution of RES to 5 per cent of the total power demand by 2015 and to 10 per cent by 2020.[28] However, as of 2022 the electricity sector of Bangladesh was still short of meeting these targets. The PSMP 2016 therefore established a less ambitious target of 10 per cent of generation from RES by 2041.[13]

Feed-in tariffs (FITs) in Bangladesh are decided through a bidding process, where the Ministry of Power, Energy and Mineral Resources (MPEMR) can impose a maximum and minimum tariff.[29] In recent years, a number of power purchase agreements (PPAs) has been made with solar power plants at a FIT rate of 6.34–12.73 BDT/kWh (0.075–0.150 USD/kWh). The PPAs are concluded for 20 years under the "no electricity no payment" principle.[17]

The cost of generation from RES in Bangladesh is much less than that of generation from non-renewable energy sources, with the exception of gas. The cost of generation is lowest for hydropower, followed by gas-fired plants and solar power, and highest for plants fuelled by diesel and heavy furnace oil as well as for wind power plants. However, the selling price of electricity to BPDB is fixed at the same rate for both renewable and non-renewable energy sources.[17] Furthermore, domestic hydropower development is not prioritized by existing strategic planning due to relatively low potential and associated socio-environmental costs. The Government of Bangladesh has instead focused on exploring joint hydropower projects in neighbouring Nepal and Bhutan.[13]

COST OF SMALL HYDROPOWER DEVELOPMENT

The cost of SHP construction, operation and maintenance in Bangladesh is highly dependent on site-specific factors and displays the greatest degree of variance among all types of RES. According to the 2015 Scaling-Up Renewable Energy Programme (SREP) Investment Plan for Bangladesh, capital investment costs for SHP ranged from 2,090 USD/kW to 6,080 USD/kW, while fixed annual operation and maintenance (O&M) costs were estimated at 57–111 USD/kW.[25] Meanwhile, a 2014 assessment of hydropower resources in Bangladesh carried out by Stream Tech estimated capital investment costs for SHP sites under 10 MW ranging from 2,400 USD/kW to 10,300 USD/kW, with fixed annual O&M costs of 72–412 USD/kW, while costs of interconnection were estimated at 500–2,380 USD/kW.[30]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Climate change in Bangladesh has led to an increase in extreme rainfall events, while glacial melt is likely to cause additional flooding in the coming decades.[5,6] Increases of mean seasonal rainfall have been particularly prominent along the coast, already the most flood-affected zone, and have been estimated at up to 42 mm/year during the monsoon season and up to 24 mm/year during the post-monsoon season. Glacial melt in the Himalayas may cause glacier mass losses of 45–68 per cent by 2100, leading to initial increases in runoff followed by the gradual drying of glacier-fed rivers in Bangladesh, as well as increased sedimentation.[5]

Increased precipitation volumes, frequency of extreme rainfall and runoff all pose risks to the development of hydropower in the country. Bangladesh is located in the delta of three major rivers and the fluvial geomorphology of the country is highly dynamic. Riverbank erosion, sedimentation and changes in the course of rivers, already widely observed in the country, are likely to increase and further complicate construction and maintenance of hydropower projects.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The most important barriers to SHP development of Bangladesh involve environmental and economic factors, including the following:

- Flat terrain in most parts of the country limiting hydropower potential;
- Dynamic fluvial geomorphology causing riverbank erosion and changes in the course of rivers;
- High population density limiting the amount of land available for SHP construction;
- High cost of SHP construction relative to potential capacity as a result of above factors;
- Lack of local technical capacity in conducting Environmental Impact Assessments;
- Future climate change impacts presenting an additional threat to potential SHP projects;
- Government plans prioritizing joint cross-border hydropower projects over domestic hydropower development.

The key factor enabling SHP development in the country is the large number of existing studies identifying potential SHP sites across the country and estimating costs.

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Bhutan

Choten Duba, Ministry of Economic Affairs

KEY FACTS

Population	748,931 (2020)[1]
Area	38,394 km^2[2]
Topography	The country has elevations ranging from as low as 160 metres in the southern foothills to over 7,000 metres above the mean average sea level. Such a wide range is attributed to the fact that Bhutan is positioned in the most rugged mountain terrains of the Himalaya Range. The snow-capped Great Himalayan Range located in the north has its peak reaching over 7,500 metres above sea level. The northern region is characterized by an arc of glaciated mountain peaks with an arctic climate at the highest elevations. Conversely, the central region has fast flowing rivers curving out gorges.[2]
Climate	The climate of Bhutan falls into three distinct climatic zones — Alpine in the northern region, temperate in the inner region and subtropical in the southern plains and foothills. The region which falls under the Alpine zone remains cold with year-round snowfall and average temperatures fluctuating between 0 °C in the winter and 10 °C in the summer. The temperate zone is associated with temperate and subtropical climate characteristics and has hot and humid climatic conditions with temperatures ranging from 15 °C to 30 °C year-round.[2]
Climate Change	An analysis of the historical climate data shows a trend of increasing temperatures (both mean seasonal and mean annual temperatures) and decreasing mean annual rainfall. The climate projections for the periods of 2021-2050 and 2070-2100 also showed a trend of surface temperature increase of 0.8-3.2 °C. It can therefore be concluded that the annual rainfall over Bhutan is likely to increase in the future under the RCP 8.5 scenario, with an increase of 10–20 per cent in the first half of the century and reaching 30 per cent by 2100.[3]
Rain Pattern	Due to large variations in elevation, the average annual precipitation in the country varies widely from 40 mm (primarily from snowfall) in the severe climate of the north to as high as 7,800 mm at some locations in the subtropical region. The temperate central region has an average annual precipitation rate of approximately 1,000 mm. The country receives most rainfall in the summer monsoon season, which commences in late June and lasts through late September.[2]
Hydrology	The main rivers of Bhutan are fed by melting snow and flow from north to south. They are augmented with numerous east-west flowing tributaries as they flow towards the foothills of the Himalayan plains and join the Brahmaputra River in India further south. The country has four major river systems: Drangme Chhu, Puna Tshang Chhu, Wang Chhu and Amo Chhu. The glaciers in the northern part of Bhutan, which cover approximately 10 per cent of the total surface area, are an important renewable source of water for the country's rivers.

ELECTRICITY SECTOR OVERVIEW

The total energy generation in Bhutan in the year 2019 was 8,876.9 GWh (Figure 1). Hydropower was the main source of electricity generation accounting for 8,875.7 GWh or 99.99 per cent of the total. Large and mega-hydropower plants dominate the country's electricity mix, while pico-, mini- and micro-hydropower plants accounted for 17.8 GWh of total generation in 2019. An additional 0.006 GWh was from diesel generators and 1.2 GWh from wind power plants (0.6 MW) in the country.[4,5] The total installed capacity of the country in 2021 was 2,343 MW (Figure 2).[5,6] The installed capacity and generation data for solar rooftop installations are not available at this point of time.

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

Source: BPC,[4] DHPS[5]

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

Source: DHPS,[5] DGPC[6]

In 2005, Bhutan embarked on a rural electrification programme with the formulation of Rural Electrification Master Programme (REMP). As of 2020, 99.97 per cent of households were electrified through either on-grid systems via grid extension or off-grid systems supplied with solar rooftop installations in places where grid extensions are not feasible. The off-grid villages consist of 1,429 households and are in the process of receiving grid extensions under the Rural Electrification Programme (Phase-2) supported by the Japan International Cooperation Agency's (JICA) funding.

As Bhutan is almost 100 per cent dependent on hydropower generation, the country's electricity sector is prone to seasonal variability in generation depending on the availability of discharge in the rivers.[4,7] Since all the existing hydropower plants in the country are run-of-river systems, they are able to operate at only approximately 20 per cent of the total installed capacity in the dry periods. During such periods the generated electricity is barely sufficient for domestic consumption, with the shortages being met through imports from India. Thus, in 2019, Bhutan imported approximately 267.8 GWh to make up for the shortage of electricity during the winter season when the river discharge is at its lowest.[6] Nevertheless, Bhutan has been a net exporter of electricity. In 2019, the net energy exports amounted to 4,053.6 GWh (over 70 per cent of the total generation), which constituted a 10 per cent increase since 2018 due to increased generation and amounting to BTN 11.9 billion (USD 164,111) of revenue for the country.[6]

The domestic demand for electricity in the country has been rising consistently over the past years except for the year 2019 when it decreased to 387.7 MW compared to 399.4 MW in 2018. This exception from the general trend may be attributed to the decreased demand from the ongoing construction of hydropower projects.[7] Overall, over the years, increasing interconnections of rural households to the central grid have added to the growing electricity demand. Usually, higher power demand occurs during the winter months (December–March) when people use electricity for heating.[4]

Under the umbrella of the Ministry of Economic Affairs, the Department of Hydropower and Power Systems (DHPS) is mandated for the development of medium (between 25 MW and 150 MW), large (between 150 MW and 1,000 MW) and mega-hydropower projects (above 1,000 MW). On the other hand, the Department of Renewable Energy is responsible for the development of small hydropower (SHP) projects with an installed capacity 25 MW and below as well as of other sources of renewable energy such as solar power, wind power and biomass.[8,9] The state-owned utility Druk Green Power Corporation Limited (DGPC) operates and maintains the hydropower assets, while Bhutan Power Corporation Limited (BPC) is responsible for the transmission and distribution of electricity in the country.[4,6] The electricity sector is regulated by Bhutan Electricity Authority (BEA).[9]

The high reliance on a single electricity source implies certain risks for the electricity sector. These are associated with the rising energy demand in sectors such as transport and industry as well as the rapid growth of fossil fuel imports to make up for the generation shortfall in the face of the inevitable impact of the climate crisis. As a contribution towards the country's pledges to remain carbon negative, the Government of Bhutan adopted the Alternative Renewable Energy Policy (AREP) 2013. Through this policy, Bhutan strives to address the situation by diversifying its energy mix and promoting an independent energy system that not only meets the national energy demand, but also enhances energy security and contributes towards environmental preservation and economic development.[8] As of the moment of writing of this chapter, the country was in the process of formulating a regulation on grid integration of alternative renewable energy sources, including SHP projects with capacity of less than 25 MW, along with tariff determination with the intention to create an enabling environment for the promotion of renewable energy.

BEA, as the regulator body for the electricity sector, is mandated to develop and implement principles and procedures for tariff setting, subsidies and economic regulation of domestic tariffs.[9] The electricity tariffs in Bhutan are guided by the Domestic Electricity Tariff Policy (DETP) and the Tariff Determination Regulation 2016 formulated by BEA in due consultation with a wide range of stakeholders. As per the aforementioned DETP and subsequent regulation, electricity tariffs shall be approved by BEA after reviewing proposals submitted by the country's utility bodies: DGPC and BPC.[10] The tariffs are subject to revision every three years.[10] Table 1 shows the existing electricity tariffs in Bhutan which shall remain valid from 1 October 2019 to 30 June 2022 and will be thereafter subject to revision at regular intervals.

Table 1. **Approved Tariff Structure of Bhutan for the Period 1 October 2019 – 30 June 2022**

Tariff block	*Monthly consumption (kWh)*	*1 October 2019 to 30 June 2020 (USD/kWh)*	*1 July 2020 to 30 June 2021 (USD/kWh)*	*1 July 2021 to 30 June 2022 (USD/kWh)*
Low voltage (LV)				
LV block I (rural)	0–100	0	0	0
LV block I (highlanders)	0–200	0	0	0
LV block I (others)	0–100	0.018	0.018	0.018
LV block II (all)	101–500	0.037	0.037	0.037

Tariff block	*Monthly consumption (kWh)*	*1 October 2019 to 30 June 2020 (USD/kWh)*	*1 July 2020 to 30 June 2021 (USD/kWh)*	*1 July 2021 to 30 June 2022 (USD/kWh)*
LV block III (all)	> 500	30.049	0.500	0.500
Low voltage bulk		0.056	0.056	0.057
Medium voltage (MV)				
Energy charges (USD/kWh)		0.031	0.034	0.036
Demand charges (USD/kVA/month)		4.470	4.470	4.470
High voltage (HV)				
Energy charges (USD/kWh)		0.021	0.021	0.021
Demand charges (USD/kVA/month)		4.020	4.020	4.020
Wheeling (USD/kWh)		0.004	0.004	0.004

Source: BEA[10]

SMALL HYDROPOWER SECTOR OVERVIEW

In Bhutan, hydropower projects with an installed capacity of less than 25 MW are categorized as SHP plants.[8,9] Further classification of SHP is shown in Table 2.

Table 2. **Classification of Small Hydropower in Bhutan**

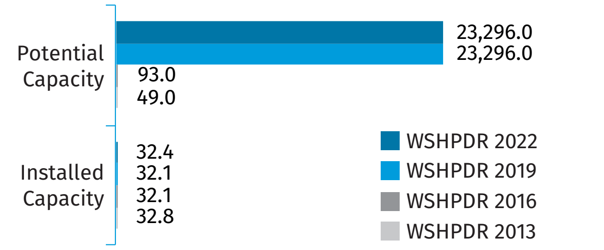
Category	*Capacity (kW)*
Pico	1–10
Micro	10–100
Mini	100–1,000
Small	1,000–25,000

Source: Department of Renewable Energy[11]

Bhutan has a total of 21 micro- and mini-hydropower plants (1–1,000 kW) with a combined installed capacity of 3.16 MW. Of these, 17 plants are managed by BPC and one each by the Department of Renewable Energy, the non-governmental organization Tarayana Foundation, the private community Gakhil Tshokpa and Thimphu District, respectively. A further four SHP plants (1–25 MW) with a total installed capacity of 29.19 MW (if the upper stage 24 MW Basochhu hydropower plant is included). Thus, the total installed capacity of SHP in Bhutan is 32.35 MW (Table 3).[7,12] According to the 10 MW definition of SHP, there are 24 existing plants with a combined installed capacity of 8.36 MW. As of 2021, a further two projects (0.53 MW) under the 10 MW definition were under investigation up to a detailed project report level. In 2019, the SHP generated a total of 122.79 GWh of electricity.[12]

The difference in installed capacity compared to the *World Small Hydropower Development Report (WSHPDR) 2019* is due to the rehabilitation of one mini-hydropower plant (Figure 3). Potential capacity has remained unchanged; however, it should be noted that the previous edition reported a wrong value, which has been corrected in the current chapter.

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



Source: BPC,[7] DHPS,[12] *WSHPDR 2013*,[13] *WSHPDR 2016*,[14] *WSHPDR 2019*[15]

Note: Data for SHP up to 25 MW.

The new estimate of the theoretical potential for SHP of less than 25 MW (23,296 MW) was announced in 2017 as part of the Renewable Energy Master Plan formulation (2017–2032). The estimate indicates that the SHP potential remains largely untapped.[16] As of 2021, three projects with a total capacity of 56.30 MW had been investigated up to the reconnaissance level and four projects up to the detailed project report. The total capacity of planned SHP projects with a capacity of less than 25 MW was 82.83 MW.[17]

As provisioned under Bhutan's Sustainable Hydropower Development Policy–2008, the country intended to harness 10,000 MW of hydropower capacity by 2020. However, the target was later reduced to 5,000 MW to be developed by 2022.[16] As per the Renewable Energy Master Plan (REMP–2016), it was estimated that Bhutan has a theoretical hydropower potential of 41,088 MW as opposed to the previous estimate of 30,000 MW. Of the current theoretical potential, 26,683 MW is considered to be economically feasible for development.[18] However, the Power System Master Plan (PSMP–2040) has established that the country has a total potential of 3,700 MW from 155 identified potential sites. The disparity between the total potential estimates quoted in REMP and PSMP is attributed solely to the different methodology used.

As a next step under REMP, an assessment of SHP potential was conducted through a desktop study. In that study a total of 148 projects with a capacity ranging from 1 MW to 25 MW were identified in the whole country with a total combined estimated installed capacity of 1,553.46 MW. This constitutes roughly 7 per cent of the theoretical potential estimated in REMP.[19]

As of 2021, Bhutan had developed a total installed hydropower capacity of 2,334 MW (10 per cent of the potential with an addition of a 720 MW hydropower plant in July 2019), inclusive of small, mini- and micro-hydropower projects.[6] Furthermore, over 2,938 MW of new hydropower capacity was in various stages of construction and 6,200 MW of potential capacity was in the pipeline planned for development.[5]

Table 3. **List of Selected Operational Small Hydropower Plants in Bhutan**

Name	*Location*	*Capacity (MW)*	*Plant type*	*Operator*	*Launch year*
Dali	Zhemgang District	0.018	Run-of-river	Tarayana Foundation	2016
Shingkhar	Bumthang District	0.009	Run-of-river	Gakhil Tshokpa	2015
Basochhu Upper Stage	Wangdue District	24.000	Run-of-river	DGPC	2009
Sengor	Mongar District	0.100	Run-of-river	DRE	2007
Chendebji	Trongsa District	0.070	Run-of-river	BPC	2005
Rongchu	Lhuentse District	0.200	Run-of-river	BPC	2001
Gangzur	Lhuentse District	0.120	Run-of-river	BPC	2000
Lingzhi	Thimphu District	0.008	Run-of-river	Thimphu District	1999
Rangjung	Trashigang District	2.200	Run-of-river	BPC	1996
Tintibi	Zhemgang District	0.200	Run-of-river	BPC	1992
Darachhu	Dagang District	0.200	Run-of-river	BPC	1992
Changchey	Changchey	0.200	Run-of-river	BPC	1991
Chumey	Bumthang District	1.737	Run-of-river	BPC	1988
Rukubji	Wangdue District	0.040	Run-of-river	BPC	1987
Tansibji	Trongsa District	0.030	Run-of-river	BPC	1987
Sherabling	Trongsa District	0.050	Run-of-river	BPC	1987
Bubja	Trongsa District	0.030	Run-of-river	BPC	1987
Tamzhing	Bumthang District	0.030	Run-of-river	BPC	1987
Ura	Bumthang District	0.030	Run-of-river	BPC	1987
Kekhar	Zhemgang District	0.020	Run-of-river	BPC	1987

Source: BPC,[7] DHPS[12]

Information pertaining to ongoing and planned SHP projects as well as potential sites available for investment is restricted from the public and thus are not presented in this chapter.

RENEWABLE ENERGY POLICY

With the objective to diversify the energy mix and also to enhance energy security, Bhutan adopted the Alternative Renewable Energy Policy (AREP) in 2013, which includes the promotion and development of other forms of renewable energy sources, including hydropower projects of installed capacity below 25 MW.[8]

The policy outlines the importance of deploying other renewable energy resources instead of depending on one single source of electricity, i.e., medium, large and mega-hydropower projects. The policy captures in depth the allocation process for the development of SHP and also elaborates on the mode of operation of projects after development (Build-Own-Operate/Build-Own-Operate-Transfer models, etc.). The policy stipulates that the developer shall be exempt from paying royalties on energy if the SHP project is developed for domestic purposes. This enables SHP to compete with the larger hydropower projects, which are comparatively cheaper and mostly destined for export.

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

The Sustainable Hydropower Development Policy–2008 outlined the requirement to develop a separate Renewable Energy Policy for the implementation of SHP projects of capacities below 25 MW and also to diversify the energy mix to enhance the energy security of the country. The concerned AREP was adopted in 2013 encompassing solar power, wind power, biomass and SHP.[8,9] However, with the intention to place more focus on the construction of ongoing larger hydropower projects, the policy did not set a target for SHP development and stipulated that one will be set in the future as needed.

As per the AREP, the development of SHP shall be allocated on the basis of open competitive bidding. If the SHP plant is meant for domestic consumption, the bidding shall be based on the lowest offered tariffs. For export-oriented projects, the tender shall be allotted to the one that offers the highest energy royalty. However, tariffs should be set with adherence to tariff regulations such as the Domestic Electricity Tariff Policy and the Tariff Determination Regulation 2016. Foreign direct investment (FDI) actors can only be allowed as minority shareholders. However, FDIs are not permitted for micro and mini hydropower projects. SHP projects are to be developed under the Build-Own-Operate-Transfer (BOOT) model for a concession period of up to 30 years, which is extendable for up to 15 years.[8] Upon the fulfilment of licence conditions, the project developer is issued with a licence to construct, operate and manage the plant(s).[20] Depending on the magnitude of the project and its environmental and social impact, the developer is required to carry out an Environmental Impact Assessment (EIA). Thereupon, an Environmental Clearance (EC) is accorded to the project developer by the National Environment

Commission (NEC), the nodal agency for administering and granting EC, regulated under the Environmental Assessment Act 2000 and the Regulation for Environmental Clearance of Projects 2002. Without an EC, the developer cannot proceed further with the project.[21]

According to the Fiscal Incentives 2016, hydropower projects introduced through the intergovernmental mode, which is a type of bilateral hydropower project development agreement, including the Associated Transmission systems, will be exempted from taxes such as sales tax (ST) and customs duty (CD). Other hydropower projects, which are to be developed through other modes shall be tax exempted (ST & CD) on machinery, materials and equipment imported for the purpose of hydropower project development.[17,22]

COST OF SMALL HYDROPOWER DEVELOPMENT

The majority of hydropower projects in the country, mostly medium- and large-scale ones, were developed under the intergovernmental mode, where certain portions of the funding consisted of grants. These made it possible to successfully realize the projects and make the cost of the energy derived from these projects much cheaper. When coupled with the subsidy scheme for domestic consumption, this makes SHP projects quite attractive. These factors have made the cost of electricity from SHP appear comparatively high.

As of 2021, electricity generation in Bhutan was dominated by medium, large and mega-hydropower plants, with the majority of projects being developed through the intergovernmental mode. The large quantity of electricity generated by larger-scale hydropower plants against their capital investment makes the cost of such projects attractive compared to other sources, including SHP. Therefore, promoting SHP in Bhutan faces a unique challenge as the country enjoys the availability of low-cost renewable electricity from larger hydropower plants. Therefore, given the current scenarios, the cost of SHP is found not to be competitive with larger-scale hydropower if only the cost of generation is considered.[8,16]

The cost of development of large hydropower projects in Bhutan ranges from BTN 70 million (USD 963,844) to BTN 90 million (USD 1,239,228). Based on detailed project reports of some SHP projects, the cost of SHP development ranges from BTN 84 million (USD 1,156,613) to as high as over BTN 1.6 billion (USD 22,030,736), with the size of the project, grid connectivity and locations being the key parameters defining the cost.[23,24,25] In the current scenario where the electrification rate has reached over 99 per cent, the remaining off-grid areas are located in the most remote parts of the country with some situated at a distance of more than nine days of walking. Supplying reliable electricity to these households has been found to be highly costly, largely due to transportation costs that can be as high as over 40 per cent of the total cost.

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

The AREP has provisioned for the establishment of the Renewable Energy Development Fund (REDF) to enable a favourable investment climate for alternative renewable energy sources, including SHP, with funds coming from various sources including a feed-in tariff (FIT), which is yet to be formulated. However, as of 2021, REDF had not been established. Noting the capital intensiveness, especially in the case of off-grid projects, the implementation of SHP in the country may be possible only through grants. Otherwise, their development would be techno-economically infeasible.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

A hydrological model simulation carried out for Bhutan by the Norwegian Water Resources & Energy Directorate (NVE) suggested that the flow in most of the streams will not change significantly from 1981–2010 to 2021–2050 for the catchments with high glacier coverage given the small changes in temperatures. After the mid-21st century, the glacier ice melt rate is projected to be higher due to increasing temperatures, which is to contribute to an increased flow volume in rivers. However, the catchments with low glacier coverage are expected to have a reduction in streamflow as a result of smaller amounts of precipitation, particularly during summer.[26] Because most of the SHP plants are located in the east-west oriented rivers with a smaller catchment area and a smaller glacier cover fraction, the reduced flow, as observed by the hydrological model, will most likely have an impact on the development of the sector. Therefore, adaptive measures, such as planning for reservoir and pump storage schemes would be a better option instead of the run-of-river type plants, which are highly dependent on seasonal flow variability.

Climate change has been affecting the precipitation pattern, impacting electricity production in the short, medium and long terms. It causes a decreased flow in other seasons and increased flooding during monsoons, which exposes hydropower facilities to the risk of floods and landslides in the rainy seasons and dwindled electricity generation in the winter due to decreased river flow.[3]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

To this date, the decision-making bodies and the public are of the view that the cost of electricity from SHP projects is higher than that from large hydropower projects. However, as per the findings of some of the SHP projects, the specific cost of generation from these small projects is comparable to, and even lower than, some of the medium-sized hydropower projects. Hence, venturing into SHP projects may not be as costly as anticipated and reported so far.

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

- Development of larger projects still appears to be more viable based on economies of scale and hence more interest is being attracted to the implementation of bigger projects;
- Implementation guidelines for developing SHP projects are not yet in place;
- FITs or any other enabling mechanisms which will make SHP projects equally viable are yet to be formulated.

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

- Equal and sometimes lower costs of SHP projects compared to medium-sized ones;
- Due to their small scale, SHP projects have a shorter construction period and hence the cost of their development is not impacted by Interest During Construction (IDC);
- The funds for SHP development can be comfortably sourced from within the country, thereby avoiding the need to look for international donors;
- Bhutan has a large energy surplus from hydropower during the monsoon season, but because of the projects being of the run-of-river type, the quantity of electricity generation decreases drastically during the dry months, during which the country has been importing power. Development of a few SHP projects could be a suitable alternative to meet this deficit during the dry months, while also supplementing the exports during monsoons;
- Considering that smaller projects can be easily funded by individuals or a consortium of firms, it can be a viable option to also explore development as the captive power to meet the industrial demands.

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India

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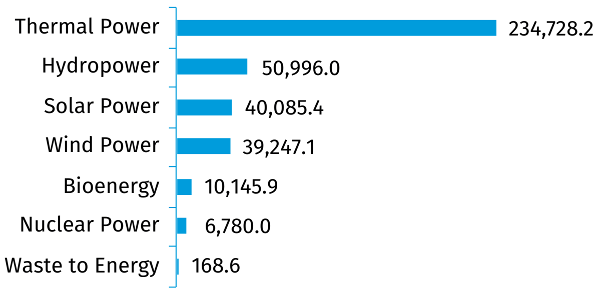
KEY FACTS

Population	1,352,621,350 (2021)[1]
Area	3,287,263 km² [2]
Topography	The south of India is characterized by an upland plain, Deccan Plateau, while flat to rolling plains are found along the Ganges River. Deserts take up most of the western part of the country and the Himalayas are located in the north with the highest point, Kanchenjunga, at 8,598 metres above sea level.[1,2]
Climate	Climate varies from tropical monsoon in the south to temperate in the north. Temperatures range between 32 °C and 38 °C in the valleys, while at the elevation of 4,500 metres the temperatures are typically below 0 °C. [1,2]
Climate Change	A significant overall impact of climate change on water resources is anticipated, including the rise in extreme variation in rainfall patterns, thereby increasing flood and drought frequency, the intensity of rainfall and spatial variability, the reduction in natural groundwater recharge and alterations in the flow of the river systems, which may significantly impact irrigation.[3]
Rain Pattern	The average annual rainfall is 1,074 mm. The monsoon season lasts from June to September with the south-west monsoon accounting for 70–95 per cent of annual rainfall in the country.[4]
Hydrology	India has numerous rivers with varying catchment areas and water resources. The catchment areas of the rivers flowing through the country are divided into 20 river basins. Of the major rivers, the Ganges–Brahmaputra–Meghna system is the largest with a catchment area of approximately 1.1 million km². The longest river is the Ganges (2,525 km). Other major rivers are the Indus, Godavari, Krishna, Mahanadi and Narmada. Many rivers are glacier-fed with most glaciers lying in the states of Sikkim, Jammu and Kashmir, Himachal Pradesh and Uttarakhand and a few glaciers in Arunachal Pradesh. The Siachen and Gangotri glaciers are two of the most important glaciers.[4]

ELECTRICITY SECTOR OVERVIEW

The total installed capacity of India, as of March 2021, was 382,151 MW, of which thermal power accounted for approximately 61 per cent, hydropower 13 per cent, wind power 10 per cent, solar power 10 per cent, biomass 3 per cent, nuclear power 2 per cent and waste for 0.04 per cent (Figure 1). The power generation infrastructure was owned by the Central and State Governments and the private sector with the shares of 26 per cent, 27 per cent and 47 per cent, respectively.[5]

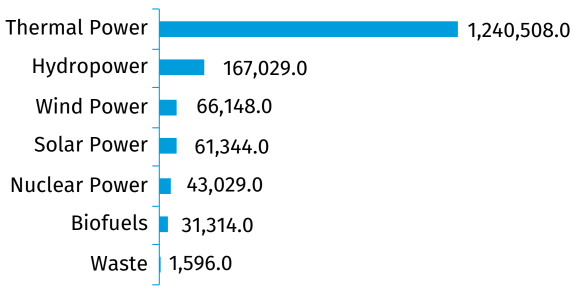
Figure 1. **Installed Electricity Capacity by Source in India in 2021 (MW)**



Source: National Power Portal[5]

Annual generation in 2020 amounted to 1,610,968 GWh. Of this, 77 per cent, or 1,240,508 GWh, came from thermal fossil fuel generation, including 72 per cent from coal. In contrast, non-hydropower renewable sources (i.e., excluding hydropower and waste) made up 158,806 GWh, or 10 per cent of the electricity generation mix.[6] Hydropower made up 10 per cent of total generation (Figure 2). Peak demand in 2020–2021 was at 190 GW, of which 0.4 per cent remained unmet.[5]

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



Source: IEA[6]

Electricity is a concurrent subject in India, meaning that the Central Government and the State Governments have the responsibility to promote its development and the authority to adopt necessary laws and regulations and to formulate and implement policies and development programmes.

The Central Electricity Regulatory Commission (CERC) at the federal level and the State Electricity Regulatory Commissions (SERCs) in the states are the statutory bodies possessing a quasi-judicial status under Section 76 of the Electricity Act (2003) and functioning as regulators of the power sector. CERC and SERCs are in charge of the electricity tariff system, transparent policies regarding subsidies and promotion of efficient and environmentally friendly policies. CERC was instituted primarily to regulate the tariffs of power generating companies owned or controlled by the Government of India and any other generating companies with a composite power generation scheme and interstate transmission. SERCs have similar functions but with jurisdiction limited to the respective state.

In 2018, the Government announced that all 657,009 villages in the country had been electrified.[4] Although all cities, towns and villages in India have access to electricity, only 86 per cent of households out of the total of 224 million do have access.[7] However, a village is considered electrified if at least 10 per cent of the homes and public buildings are connected to the grid, leaving some uncertainty as to how many households actually have access to electricity.[8] Officially, much progress has been made, with only 0.07 per cent of households remaining to be electrified as of 31 March 2019, all of which come from the state of Chhattisgarh.[9]

To improve electricity access, construction of new power plants as well renovation of existing plants is underway. Average power purchase cost in India in March 2021 was approximately USD 0.0513 (INR 3.85) per kWh.[10] In reality, tariffs vary from state to state, with each state having a unique tariffication system. In 2021, tariffs in Andhra Pradesh ranged from 1.45 INR/kWh (0.019 USD/kWh) to 9.95 INR/kWh (0.13 USD/kWh), depending on consumption groups and amount of monthly consumption. In contrast, tariffs in the state of Bihar range from 6.1 INR/kWh to 7.4 INR/kWh (0.082–0.099 USD/kWh).[11]

SMALL HYDROPOWER SECTOR OVERVIEW

The definition of small hydropower (SHP) in India is up to 25 MW (Table 1).

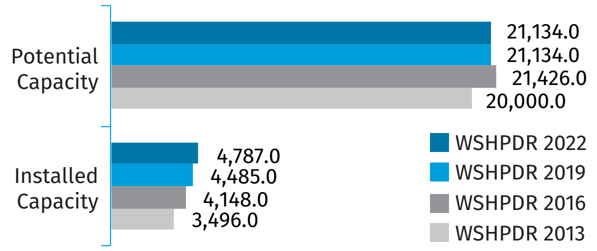
The installed capacity of SHP connected to the grid in India, as of March 2021, was 4,787 MW, while the potential was estimated to be 21,134 MW, indicating that 22 per cent has been developed (Figure 3).[12,13] Compared to the *World Small Hydropower Development Report* (WSHPDR) 2019, installed capacity has increased by approximately 7 per cent due to the introduction of new plants, whereas the potential has remained unchanged. The states with the most abundant hydropower capacity are Karnataka with 1,281 MW and Himachal Pradesh with 912 MW as of 31 March 2020.[14]

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

Category	*Capacity (kW)*
Pico/watermill	Up to 5
Micro	Up to 100
Mini	101–2,000
Small	2,001–25,000

Source: MNRE[8]

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



Source: MNRE,[12,13] *WSHPDR 2013*,[14] *WSHPDR 2016*,[15] *WSHPDR 2019*[16]

The details on potential and installed SHP capacity by state are provided in Table 2. Moreover, there are also off-grid plants. While there are no data available on these, their combined installed capacity is estimated be in the order of 200 MW, or 4 per cent of total SHP installed capacity.

Table 2. **Status of Small Hydropower Development in India**

State	*Identified potential*		*Commissioned*		*Under development*	
	Number of sites	*Total capacity (MW)*	*Number of plants*	*Capacity (MW)*	*Number of projects*	*Total capacity (MW)*
Andhra Pradesh	359	409.32	44	162.11	–	–
Arunachal Pradesh	800	2,064.92	156	131.11	9	6.05
Assam	106	201.99	6	34.11	1	2.00
Bihar	139	526.98	29	70.70	–	–
Chhattisgarh	199	1,098.2	10	76.00	–	–
Goa	7	4.70	1	0.05	–	–
Gujarat	292	201.97	17	82.69	5	28.47
Haryana	33	107.40	9	73.50	–	–
Himachal Pradesh	1,049	3,460.34	197	936.11	12	127.00
UT of J& Kashmir	103	1,311.79	19	146.34	6	31.90

State	*Identified potential*		*Commissioned*		*Under development*	
	Number of sites	*Total capacity (MW)*	*Number of plants*	*Capacity (MW)*	*Number of projects*	*Total capacity (MW)*
UT of Ladakh	199	395.65	29	39.64	9	10.15
Jharkhand	121	227.96	6	4.05	–	–
Karnataka	618	3,726.49	170	1,280.73	3	13.00
Kerala	238	647.15	35	230.02	7	72.50
Madhya Pradesh	299	820.44	13	99.71	2	7.60
Maharashtra	270	786.46	70	379.58	9	10.40
Manipur	110	99.95	8	5.45	–	–
Meghalaya	97	230.05	5	32.53	2	25.50
Mizoram	72	168.90	18	36.47	2	8.50
Nagaland	98	182.18	12	30.67	1	1.00
Odisha	220	286.22	11	88.63	2	33.00
Punjab	375	578.28	56	173.55	6	4.30
Rajasthan	64	51.67	10	23.85	–	–
Sikkim	88	266.64	17	52.11	1	3.00
Tamil Nadu	191	604.46	21	123.05	–	–
Telangana	94	102.25	30	90.87	–	–
Tripura	13	46.86	3	16.01	–	–
Andaman and Nicobar Islands	7	7.27	1	5.25	–	–
Uttar Pradesh	251	460.75	9	49.10	1	1.50
Uttarakhand	442	1,664.31	102	214.32	14	28.58
West Bengal	179	392.06	24	98.50	–	–
Total	**7,133**	**21,133.62**	**1,138**	**4,786.81**	**92**	**414.45**

Source: MNRE[13]

As of March 2021, the potential of SHP (less than 25 MW) in India was estimated at approximately 21,134 MW with 7,133 identified sites. Of these, 4,488 sites (15,536 MW or 74 per cent of the total SHP potential) are located on small streams (run-of-river), 364 sites (1,558 MW or 7 per cent of the total SHP potential) are located on existing irrigation dams and 2,281 sites (4,040 MW or 19 per cent of the total SHP potential) are located on existing canals, falls and barrages.[14] Efforts are underway for a potential assessment of existing facilities such as pipelines for drinking water and industrial use, effluent outfall at water and sewage treatment plants, outlets of small dams and hydrokinetics in flowing channels and streams. Due to the availability of suitable turbines, ultra-low head potential (below 3 metres) is also being investigated and explored. A few installations on ultra-low head projects, such as irrigation canals and wastewater outlets, have been commissioned recently. The use of small-scale pumped-storage plants in the future is also being contemplated. Several operational sites that benefited from the Renewable Energy Certificate programme are listed in Table 3.

Table 3. **List of Selected Operational Small Hydropower Plants in India**

Name	*Location*	*Capacity (MW)*	*Operator*	*Launch year*
Khandi SHPP	District Kargil, UT of Ladakh	1.0	Kargil Renewable Energy Development Agency	2020
Baitarani SHPP	Keonjhar District of Odisha	24.0	N/A	2020
Matayeen SHPP	District Kargil, UT of Ladakh	0.6	Kargil Renewable Energy Development Agency	2020
Kachchh Branch Canal, SHPP-1, Banaskantha	Gujarat	10.0	Sardar Sarovar Narmada Nigam Limited	2020
Ichoo SHPP, Anantnag	Jammu & Kashmir	5.0	O2Z Trading and Industries Pvt. Ltd	2020
Amhata-III SHPP, Rewa	Madhya Pradesh	3.8	Amhata Hydro Energy Pvt. Ltd.	2020
Dhukwan SHPP, Jhansi	Uttar Pradesh	24.0	THDC India Limited	2020
Dikshi SHPP	West Kameng, Arunachal Pradesh	24.0	N/A	2019
Nuranang SHPP	Tawang, Arunachal Pradesh	1.0	N/A	2019
Zhangdongrong SHPP	West Kameng, Arunachal Pradesh	1.0	N/A	2018
Chilong SHPP	Chilong, Tai-suru, Kargil, Jammu & Kashmir	1.0	N/A	--
Biaras SHPP	Drass, Kargil, Jammu and Kashmir	1.3	N/A	2017
Turtuk MHPP	Ladakh	0.5	Ladakh Renewable Energy Development Agency	–

Source: MNRE[8,17]

Note: Plants listed are registered under the Renewable Energy Certificate programme.

The allotment of small and large hydropower projects is within the responsibility of the respective states. The State Governments' concern lies within the maximization of revenue for the state by way of free power and return on equity in the project. Presently, free power is to be given by hydropower producers to the state. However, in many states free power for SHP projects is nil or lower than 12 per cent. States are following different models for allocation (licensing/concession) of hydropower projects to private developers. While some states are allocating projects on the basis of per MW upfront payment to the state, others are making allocations on the basis of equity participation of the state at the cost of the developer or additional free power over and above the minimum prescribed percentage. States allocate projects to independent power producers (IPPs) with conditions that the project should revert back to the state after periods varying from 30 to 45 years. In a few states, projects up to and below 2 MW are reserved for licensing to entrepreneurs from these states only.

The Indian Ministry of New and Renewable Energy (MNRE) has a mandate on small-scale hydropower up to 25 MW at the federal level. Today, the SHP development programme is essentially driven by private investment in the different states. The focus of the programme is to lower the cost of construction, increase its reliability and set up projects in areas which give the maximum advantage in terms of capacity utilization. India has developed SHP on its existing irrigation dams and irrigation canal falls. From 1997 to 2015, approximately 1,100 MW has been developed on these existing facilities and are the first choice for the development by IPPs.[13]

Identified potential hydropower sites can be accessed from the Ministry of New and Renewable Energy Website.[14]

To make SHP cost-effective and reliable, 27 documents (standards, guidelines and manuals) covering the full range of SHP activities have been developed by the Department of Hydro and Renewable Energy (HRED), Indian Institute of Technology (IIT) Roorkee with support from MNRE through a consultative process. These documents are available for use by developers, manufactures, consultants, regulators and other interested parties.[18] An international-level hydropower turbine research and development laboratory serving as a design and validation facility, in addition to conducting research on hydropower turbines and other hydropower mechanical equipment conforming to national and international standards, has been established at HRED. The guiding framework for this laboratory meets international standards (IEC 60193 and ISO/IEC 17025).[19]

RENEWABLE ENERGY POLICY

At the 2015 Conference of the Parties in Paris, the Government of India announced ambitions to achieve approximately 40 per cent of cumulative installed capacity from non-fossil fuel-based resources and to reduce the emissions intensity of the Gross Domestic Product (GDP) by 33–35 per cent from the 2005 levels by 2030. By 2022, the country aims to have 175 GW of installed renewable electricity capacity as a short-term goal. To increase investment in renewable electricity in a cost-effective way, India has introduced national competitive auctions for wind power and solar photovoltaics and also supports measures such as Renewable Purchase Obligations.[20]

MNRE has the mission to ensure energy security through development and deployment of alternative fuels, such as hydrogen, biofuels and synthetic fuels, increase the share of renewable energy, energy availability and access, energy affordability (through cost-competitive, convenient, safe, affordable and reliable energy supply options) and energy equity in terms of per capita energy consumption at par with the global average level by 2050 through a sustainable and diverse generation mix.[8] The Indian Electricity Act 2003 has special provisions for the encouragement of the development of renewable energy and rural electrification. A new Renewable Energy Act 2015 has been drafted by the MNRE and at the moment of writing of this chapter, was under revision in the Indian Parliament.[13]

A Central Electricity Authority (CEA) study of the optimal generation mix for the year 2030 suggested that battery storage of 27 GW with four hours of duration and a pumped-storage project of 10 GW is required to sustain the renewable energy capacity added into the grid.[21] This should unlock an opportunity for developing pumped-storage projects in India, which would include some SHP.

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

In August 1998 and thereafter in November 2008 and in March 2019, the Government of India announced a Policy on Hydro Power Development.[7] The Government has also prepared a policy amendment for hydropower projects, which at the moment of writing of this chapter was undergoing Government approval. Under this amendment, special funding, support on cost for infrastructure such as roads, bridges, flood protection and hydropower purchase obligation by Distribution Companies (DISCOM) has been announced.[7] Citizens adversely affected by hydropower projects have been made long-term beneficiary stakeholders in these projects by way of 1 per cent of free power on a recurring basis with a matching 1 per cent support from the State Government for local area development, as well as annual cash benefits, ensuring a regular stream of benefits. To enable the project developer in the hydropower sector to achieve a reasonable and quick return on investment, merchant sale of up to a maximum of 40 per cent of the marketable electricity has been allowed.[7]

The Central Government advises on hydropower matters and plays the role of an overall river basin planner and arbitrator. The MNRE issued guidelines for the State Governments regarding the development of policies on renewable energy development, notably for SHP.

The main points characterizing SHP and more broadly renewable energy policies of State Governments include:

- 24 States, namely Arunachal Pradesh, Andhra Pradesh, Assam, Bihar, Chhattisgarh, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Mizoram, Orissa, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttarakhand, Uttar Pradesh and West Bengal, announced policies for setting up commercial SHP proj-

ects through private sector participation. The facilities available in the states include wheeling of power produced, banking, buy-back of power and facilities for third party sale;
- SHP sites with a combined capacity of over 7,000 MW have been allotted to the private sector for development;
- Many states permit power banking, i.e., supply to the grid of electricity surplus generated by an IPP in the rainy season in exchange of the receipt of the same amount of electricity from the grid in the dry season, for a period of a few months to one year;
- Buy-back of SHP is generally based on the guidelines issued by the CERC, with variations dependent on the respective SERCs;
- Some states provide other concessions such as lease of land, exemption from electricity duty and entry tax on power generation equipment;
- Some states (e.g., Punjab, Assam, Bihar, etc.) do not levy any water use charges on the quantity of water or head used by the power plant, while some levy it as a percentage of electricity tariffs;
- Some states have prescribed the minimum share of power to be produced from renewable sources and a renewable purchase obligation for up to 10 per cent to be purchased by a State Distribution Licensee in an incremental manner. Renewable Energy Certificate (REC) trading is not very successful in the country. However, power producers have demanded that the Government include SHP under hydropower purchase obligation;
- Some states have imposed a minimum environmental flow during the dry season and monitoring is preformed using automatic devices, with real-time data being published online. Some states have not implemented environmental flow regulations, which has attracted protests of activists.[20]

COST OF SMALL HYDROPOWER DEVELOPMENT

The costs of SHP projects commissioned during the last years in India have been compiled and analysed. The capital costs of the projects have gone up from INR 50 million (USD 0.74 million) per MW to INR 110 million (USD 1.48 million) per MW from 2005 to 2020, respectively.[22]

In hilly areas in particular, 60–70 per cent of project costs is related to civil works. Long-term hydrological data are not available, with variations in discharge being common phenomena and many projects having suffered on this account. For this reason, many green SHP projects may not be suitable for tariff bidding.[23]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

The Indian Renewable Energy Development Agency (IREDA) under MNRE is a dedicated financial institution that provides loans and carries out other activities for the promotion of renewable energy sources, including SHP. Other financial institutions involved in the sector include Power Finance Corporation Limited, Rural Electrification Corporation Limited, the Industrial Development Bank of India and all commercial and private banks. Multinational financial institutions, such as the World Bank and the Asian Development Bank, have started providing funds for specific projects aiming to promote clean energy in India, normally through the above-mentioned financial institutions.

Along with other renewable energy sources, the Government of India provides a subsidy for the development of SHP for public, society and private sector in different proportions depending on the location, degree of difficulty and installed capacity. RECs are also offered as part of the Renewable Purchase Obligation programme, under which many SHP projects have benefited. Thus, 30 SHP generators were accredited as of July 2021.[24]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

A sociological survey of Himachal Pradesh has noted the impacts of SHP on local springs, which have been disappearing in some cases due to the construction of tunnels for hydropower plants. The same study highlights the frequency of disasters such as earthquakes, floods and landslides that affect the region, which would also have an impact on SHP.[25] These impacts are likely to increase in frequency as climate change progresses.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

There are several barriers for SHP development in India and these vary from state to state, depending on the availability of discharge data, site, feasibility reports and clearances. These barriers may be summarized as follows:
- Long process of obtaining project licences, clearances, permissions and finances;
- Lack of involvement of local people;
- Lack of clarity regarding the ownership of SHP projects by State Governments as each project receives support of the corresponding State Government in the form of water royalty, local area development, assistance, etc.;
- Local populations and activists consider SHP the same as large hydropower in terms of environmental, rehabilitation and resettlement implications and protest against SHP projects, too;
- Due to a continuous increase in capital costs of SHP

projects, the increasing burden of various financial loading such as water use tax, load tax, transmission charges, right of way charges and environmental flow as well as the difficult and time-consuming process of obtaining forest land on lease, the private sector does not find SHP attractive for investment. The SHP-based tariff is being compared with solar power, which receives several concessions;
- Lack of government initiative and will to fight the legal matter in courts, which causes a delay in implementation, thus increasing the costs and making tariffs non-competitive;
- Mismatch between the announced policies and their application on the level of field offices, resulting in delays in clearances and execution;
- Lack of available discharge data;
- Lack of available suitable spare parts and grid infrastructure for power evacuation.

The following points summarize the main enabling factors for SHP in India:
- A strong groundwork of data for potential sites to be developed in each state;
- Government support in the form of a subsidy that is available for SHP projects;
- A dedicated loan institution under IREDA;
- Several policy mechanisms dedicated to the regulation of the SHP sector;
- Funding support available for infrastructure costs;
- Hydropower purchase obligation for distribution companies;
- Documents (standards, guidelines and manuals) covering the full range of SHP activities have been developed by the Department of Hydro and Renewable Energy (HRED), Indian Institute of Technology (IIT) Roorkee with support from MNRE through a consultative process.

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Islamic Republic of Iran

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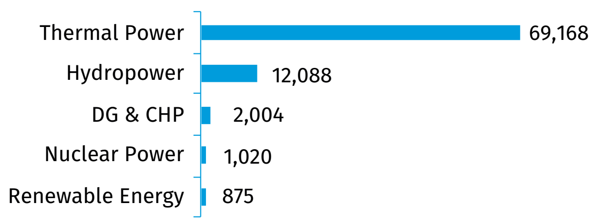
KEY FACTS

Population	82,913,906 (2019)[1]
Area	1,648,000km^2 [2]
Topography	Iran is situated on a plateau at an average elevation of 1,200 metres above sea level. The Zagros and Elburz Mountain Ranges form a V shape upon the plateau, with the apex in the north-west, while the area between the two mountain ranges is covered in salt flats and barren deserts. Mount Damavand, north-east of Tehran and the highest point in the country, rises to 5,671 metres, while the Caspian littoral region is situated below sea level. Iran is geologically unstable and occasionally experiences severe earthquakes.[2]
Climate	Iran has a continental type of climate. The skies are clear on more than half the days during the year and seasonal transitions are rapid.[2] January is the coldest month, with temperatures ranging from 5 °C to 10 °C, while August is the hottest, with temperatures ranging from 20 °C to 30 °C or more.[3]
Climate Change	According to the Third National Communication of Iran to the United Nations Framework Convention on Climate Change, the mean annual temperature for the period 2016–2030 is expected to increase by 0.2-1.4 °C in different parts of the country, relative to the period 1982-2009. Precipitation for the period 2016-2030 is projected to decrease in the spring, autumn and winter by 10-20 per cent in the eastern, north-western and south-western parts of the country and by 30 per cent in the spring in the southern part of the country, relative to the period 1982–2009.[4]
Rain Pattern	Average annual precipitation in Iran varies from less than 50 mm in the south-east to 1,980 mm in the Caspian region; the annual average precipitation for the country as a whole is approximately 400 mm. Over half of the annual precipitation falls during the winter period.[5]
Hydrology	Iran has three large rivers: the Kārūn, Sefīd and Zāyandeh. The Karun River originates in the Zargos Mountains and flows to Shatt Al-Arab in the south, emptying into the Persian Gulf. The Sefīd River originates in the Elburz Mountains in the north, flowing out onto the Gilan plain and emptying into the Caspian Sea. The Zāyandeh River flows from its source in the Zargos Mountains in a south-easterly direction, terminating in the Gāvkhāneh Marsh. Other streams in Iran are primarily seasonal with a highly variable flow, causing regular floods in the spring but drying up during the summer. The largest lake in the country is Lake Urmia in the north-west, with an area of approximately 5,200–6,000 km^2.[5]

ELECTRICITY SECTOR OVERVIEW

In March 2021, the total installed capacity of the Islamic Republic of Iran was 85,155 MW, with thermal power plants providing over 81 per cent of the total capacity, hydropower plants 14 per cent, distributed generation (DG) and combined heat and power (CHP) plants 2 per cent, nuclear power plants 1 per cent and other renewable energy sources (wind power, solar power and biofuels) approximately 1 per cent (Figure 1). Compared with the *World Small Hydropower Development Report (WSHPDR) 2019*, the total installed capacity of Iran increased by 15 per cent, largely as a result of the expansion of thermal power, including gas and combined cycle plants.[6,7]

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

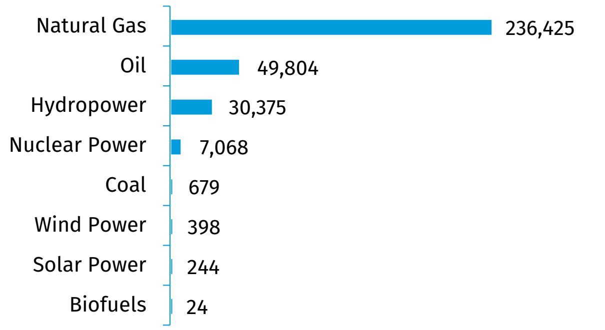


Source: MOE[6]

Total gross electricity generation in 2020 reached 334,445 GWh.[6] However, the last year for which disaggregated data on generation is available, was 2019, when total gross generation reached 325,017 GWh. Of this total, natural gas-fired power plants generated 73 per cent, oil-fired plants 15 per cent, hydropower plants 9 per cent, nuclear power plants

2 per cent and both coal-fired power and other renewable energy sources less than 1 per cent (Figure 2).[8] Thus, the majority of electricity generation in 2019 was provided by fossil fuels (88 percent).

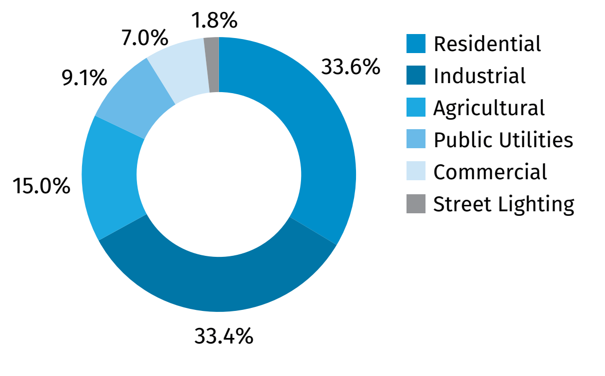
Figure 2. **Annual Electricity Generation by Source in Iran in 2019 (GWh)**



Source: IEA[8]

In 2018/2019 (Iranian year lasting from March 2018 to March 2019), electricity consumption equalled 261.4 TWh, representing a 3 per cent increase over the previous year. Consumption was dominated by the residential sector (87.7 TWh) and the industrial sector (87.4 TWh), with public utilities, commercial and agricultural sectors and street lighting consuming a combined total of 86.2 TWh (Figure 3).[9] In 2018/2019, Iran exported 6.3 TWh of electricity, representing a 23 per cent decrease over the year 2017/2018, and imported 2.6 TWh of electricity, representing a 34 per cent decrease over the previous year. With generation reaching 310.9 TWh in 2018/2019, electricity losses that year equalled 45.8 TWh, or approximately 15 per cent of total electricity supply.[9] The national electrification rate was 99.1 percent in 2019.[10]

Figure 3. **Electricity Consumption by Sector in Iran in 2018/2019 (%)**



Source: Central Bank of the Islamic Republic of Iran[9]

In 2016, building on the experience of the construction and operation of the first unit of the Bushehr nuclear power plant, the Atomic Energy Organization of Iran prepared tender documents for the construction of two new nuclear power plants of the third-generation pressurized light-water reactor type. The two additional plants will also be located at Bushehr and will have a capacity of 1,057 MW each. The construction plan is in line with the targets and legislation of the Islamic Consultative Assembly (the Parliament), specifically, with the goal of increasing the country's nuclear power installed capacity to 20,000 MW. The plans follow regulations on nuclear power used internationally as well as the recommendations of the International Atomic Energy Agency. Construction of unit 2 of the Bushehr nuclear power plant commenced in 2019 and it is expected to enter commercial operation in 2024.[11,12]

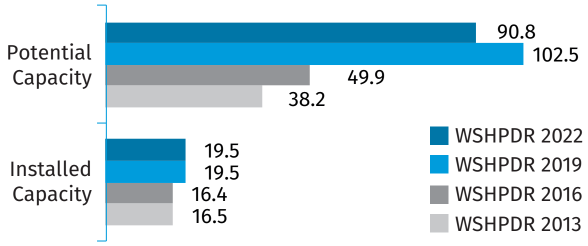
The electricity tariff rates for different classes of consumers are determined based on the average tariff by the Ministry of Energy (MOE). The average tariff is defined based on a number of estimations including availability for sale, revenue, capital and operating expenditure.[13] In 2019, the consumer tariff for electricity was approximately 0.007 USD/kWh.[14]

In order to control the budget deficit and to manage excess energy consumption, in February 2010 the Government embarked on an aggressive and ambitious price reform. According to the Targeted Subsidies Law, fossil fuel (petrol, oil, liquefied gas and kerosene) prices were supposed to rise by up to 90 per cent within five years and electricity prices would also increase to cover generation costs. In the first year of implementation, the plan was expected to generate approximately USD 10–20 billion in revenue. The generated funds were to be allocated as follows: 50 per cent to be distributed in the form of cash handouts to households, 30 per cent to support industries affected by the energy price hikes, public transportation and infrastructure and 20 per cent to cover discretionary expenses. The subsidy reform faced a number of delays, leading to the deferment of its completion until March 2021, as stated in the Sixth Five-Year Development Plan of Iran.[15,16]

SMALL HYDROPOWER SECTOR OVERVIEW

The definition of small hydropower (SHP) in Iran is up to 10 MW. As of early 2021, there were 10 SHP plants in operation (Table 1) with a total installed capacity of 19.50 MW.[17] Furthermore, the Sooleh Dokal SHP plant (4.4 MW), Zivakeh SHP plant (6.0 MW) and Zayande Roud regulator dam (8.5 MW) are currently under construction or ready to begin construction (Table 2).[17] A further 52.48 MW of capacity are available for investment.[17] While there is lack of clear information on the country's potential SHP capacity, based on the sum of capacities of existing plants, ongoing projects and potential SHP sites, total potential capacity is estimated to be at least 90.83 MW, with 71.33 MW remaining undeveloped. Accordingly, compared to the *WSHPDR 2019*, the installed capacity of SHP in Iran has not changed, while the economically feasible potential capacity decreased by 11.65 MW (Figure 4). This reduction is due to the cancellation of some potential projects since 2019.[17]

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



Source: *WSHPDR 2019*,[7] IWPCO,[17] *WSHPDR 2013*,[18] *WSHPDR 2016*[19]

The Government-owned Iran Water and Power Development Company (IWPCO) is responsible for hydropower development projects as well as the operation and development of water supply facilities. Iran Water Resources Management Company (IWRM) provides administrative support for effective operation of water resources and development of hydropower potential capacities in the country.[7]

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

Project name	*Location (province)*	*Capacity (MW)*	*Operator*	*Launch year*
Arde	Gilan	0.13	MOE	1991
Darre Takht 1	Lorestan	0.68	MOE	2005
Darre Takht 2	Lorestan	0.90	MOE	2005
Gamasiab	Hamedan	2.80	MOE	1999
Micro Power Plants	-	0.23	MOE	2004
Piran	Kermanshah	8.40	MOE	2011
Sarrud	Khorasan	0.07	MOE	1987
Shahid Azimi	-	1.00	MOE	1995
Shahid Talebi	Fars	2.25	MOE	1994
Tarik	Gilan	3.00	MOE	N/A
Total		**19.45***		

Source: IWPCO[17]

Note: Discrepancy is due to rounding.

Table 2. **List of Ongoing and Planned Small Hydropower Projects in Iran**

Project name	*Location*	*Capacity (MW)*	*Developer*	*Planned launch year*	*Development stage*
Sooleh Dokal	West Azarbayjan	4.4	IWPCO	N/A	Construction
Zayande Roud regulator dam	Isfahan	8.5	IWPCO	N/A	Ready for construction
Zivakeh	West Azarbayjan	6.0	IWPCO	N/A	Ready for construction
Total		**18.9**			

Source: IWPCO[17]

SMALL HYDROPOWER PROJECTS AVAILABLE FOR INVESTMENT

As of 2021, 52.48 MW of SHP capacity with total potential generation of 231.36 GWh per year was available for investment (Table 3).[17]

Table 3. **Small Hydropower Projects Available for Investment in Iran in 2021**

Project name	*Province*	*Capacity (MW)*	*Annual generation (GWh)*	*Type of site*
Alamoot Rood	Qazvin	1.7	9.4	New
Masuleh1	Gilan	1.8	9.4	New
Nari	West Azarbayjan	2.5	9.6	New
Nokhan1	Kermanshah	2.2	7.4	New
Taleqhan Rood	Tehran	2.5	14.9	New

Source: IWPCO[17]

RENEWABLE ENERGY POLICY

The Renewable Energy Organization of Iran (SUNA) was established in 1996 to evaluate the county's renewable energy potential, to implement renewable energy projects and to guarantee the purchase of any electricity generated from renewable sources in order to attract private sector participation in this field. Subsequently, SUNA became tasked with all matters related to renewable energy and energy efficiency.[20] In 2017, responsibility for implementing the country's renewable energy plan was transferred to the Renewable Energy and Energy Efficiency Organization (SATBA), an organization operating directly under MOE and endowed with additional power and financial resources.[21] One of the key responsibilities of SATBA is facilitating the influx of foreign investment into the renewable energy infrastructure of Iran, accomplished in part through the Foreign Investment Promotion and Protection Act (FIPPA). The Act provides mechanisms for profit transfers abroad and dispute resolution, protections against expropriation or nationalization of assets and support in acquiring visas and work permits for foreign nationals, among other provisions.[22]

The Government has been pushing for a shift away from the use of fossil fuels for electricity generation, which would allow freeing up oil and gas resources for export and ensuring more cost-effective electricity production. In the Fifth Five-Year Development Plan (2010–2015), the Government of Iran announced plans to install 5,000 MW of renewable energy (wind and solar power) by providing incentives, such as minimum tariff rates, for private investment in the sector. However, this target was too ambitious considering the relative state of development of the renewable energy sector in Iran at the time. Implementation was also set back by the impact of international sanctions and unilateral coercive measures. The Sixth Five-Year Development Plan (2016–2020) extended the date for the original 5,000 MW renewable energy target to 2020, and stipulated the development of an additional 2,500 MW of renewable capacity by 2030. The Iranian Power Generation, Transmission, Distribution and Management Company (TAVANIR), estimated that by 2021 the country's renewable energy capacity would be able to meet 10 per cent of the total energy demand.[20]

According to the announcement of the Minister of Energy dated 8 May 2016, electricity consumers can produce their own electricity using rooftop photovoltaic panels of up to 100 kW and small wind turbines of up to 1 MW. The generated electricity can be fed into the distribution grid limited to the connection capacity. Producers can refer to their electrical distribution company and sign a Power Purchase Agreement based on specified tariffs (Table 4), which are guaranteed for a 20-year period.[23] Starting from the first day of the second 10-year period and until the end of the contract, all tariffs except those for wind power plants will be multiplied by 0.7; for wind power plants with a capacity factor of 40 per cent or more, the tariff will be multiplied by 0.4; for wind power plants with a capacity factor of 20–40 per cent, by an appropriate coefficient; and for wind power plants with a capacity factor of below 20 per cent, the tariff will remain the same. Additionally, the tariffs will be adjusted annually based on currency exchange rate fluctuations and retail prices for products. Tariffs can be increased up to a maximum of 30 per cent based on the level of use of local know-how, design and manufacturing in construction. A transmission service rate, announced by Iran Grid Management Company, will be added to the payment tariff for power plants connected to the distribution grid.[24]

Table 4. **Guaranteed Renewable Energy Purchase Tariffs in Iran**

Technology type	*Guaranteed electricity purchase tariff (IRR/kWh (USD/kWh))*
Biomass: landfill	4,050 (0.10)
Biomass: other biochemical processes	5,250 (0.12)
Biomass: all thermal processes	5,550 (0.13)
Geothermal power (including excavation and equipment)	6,370 (0.15)
Electricity generation from waste heat recovery in industrial processes	3,770 (0.09)
SHP (≤ 10 MW): installations on rivers or streams	4,940 (0.12)
SHP (≤ 10 MW): installations on pipelines and side facility of dams (dam and transmission lines)	4,225 (0.10)
Fuel cell systems	6,432 (0.15)
Turbo expanders	2,080 (0.05)
Wind power: ≤ 10 MW	5,460 (0.13)
Wind power: ≤ 1 MW	7,410 (0.18)
Solar power: ≤ 10 MW	6,370 (0.15)
Solar power: ≤ 100 kW	9,100 (0.22)
Solar power: ≤ 20 kW	10,400 (0.25)

Source: SATBA[24]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

Water resources in Iran are utilized according to governmental water laws and nationalization plans initiated in 1968. The 1968 Iran Water Law and the Manner of Water Nationalization provided for licensing, duties, water charges and dues, water rights and use permits, as well as for the nationalization of river basins and other water resources and the public use of water resources.[25] More recent pieces of legislation regulating water resources in Iran have included the Law on Equitable Distribution of Water Resources (1983), Strategies for Long-Term Development of the Water Resources of the Country (2003) and the Regulation on Creation of a Balance between Water Resources and Water Use (2008), among others.[26]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Climate change is expected to have considerable impacts on the future productivity of hydropower in Iran. In parallel with the temperature and precipitation fluctuations described earlier, significant decreases in runoff are projected for the 2015–2030 period relative to the period 1982–2009. In particular, the Bandar Abbas-Sedij, Karkheh and Karoun River basins are expected to undergo reductions in runoff of 66, 61 and 55 per cent, respectively.[4] In the case of the Karkheh River basin, the third largest in Iran and representative of other basins in the region, numerical modelling of the impact of various climate change scenarios on the productivity of currently operational hydropower plants across three time periods — 2020s, 2050s and 2080s — suggests a reduction in annual generation of 15–24 per cent in the latter two periods, relative to historical data, and an up to 36 per cent reduction in generation during springtime.[27]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The barriers to the development of SHP in Iran as described in the *WSHPDR 2019* still persist and include:

- Limited water resources and future adverse impacts of climate change;
- A greater focus on the development of medium and large hydropower plants;
- Lack of investment delaying the realization of some projects.

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- Factors enabling SHP development in the country include:
- Recent reorganization in MOE, which is expected to benefit renewable energy development in general, especially in regard to foreign investment in such projects in Iran;
- Existence of feed-in tariffs for SHP that additionally factor in bonus payments for the use of local know-how and equipment in construction.

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28.

Nepal

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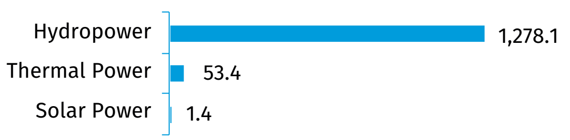
KEY FACTS

Population	30,541,477 (2021)[1]
Area	147,181 km^2 [2]
Topography	The territory of Nepal can be divided into three topographic regions. In southern Nepal lies the Terai plain. The second and largest region of Nepal is formed by the Mahabharat, Churia and Himalayan Mountain Ranges, which extend from east to west. The third region, known as the Kathmandu Valley or the Valley of Nepal, is a high central region, located between the main Himalayan and Mahabharat ranges. The highest peak is Mount Everest (Sagarmatha), at 8,848.86 metres.[2]
Climate	Influenced by the maritime and continental factors, the climate of Nepal has four distinct seasons. Spring (March to May) is warm, with showers and temperatures averaging 22 °C. Summer (June to August) is the monsoon season, with temperatures up to 30 °C. Autumn (September to November) is cool, with clear skies and temperatures reaching a maximum of 25 °C and a minimum of 10 °C. Winter (December to February) is cold, with temperatures sometimes below 0 °C at night.[3]
Climate Change	A gradual rise in maximum temperatures across Nepal has been observed between 1974 and 2014, with an average annual rise of 0.056 °C nationwide and reaching 0.12 °C in certain mountain regions during the winter season. Meanwhile, some lowland regions have experienced a slight decrease in maximum temperatures and an associated increase in the duration of fog episodes. The duration of warm spells and the number of warm days has also seen an increasing trend. Projections of climate change in Nepal predict an increase in average annual temperatures of 0.92–1.07 °C between 2016 and 2045 and of 1.3–1.8 °C between 2036 and 2065, relative to the 1981–2010 baseline period.[4]
Rain Pattern	Mean annual rainfall ranges from 250 mm in north-central Nepal, near the Tibetan plateau, to above 5,000 mm on the southern slopes of the Annapurna Range in central Nepal. Approximately 80 per cent of rainfall occurs in the monsoon period from June to September. Snowfall is confined to the northern and western mountainous regions, especially at elevations above 3,500 metres. The contribution of snow to precipitation is approximately 10 per cent of total rainfall.[3]
Hydrology	There are approximately 6,000 rivers in Nepal with a catchment area of 194,471 km^2, of which 74 per cent lies in Nepal. The rivers can be broadly divided into three categories according to their origin. The first category comprises the four main river systems of the country: the Koshi, Gandaki, Karnali and Mahakali River systems, all of which originate from glaciers and snow-fed lakes. These are perennial rivers with a significant flow even during the dry season. Rivers originating from the Mahabharat Range or midlands, such as the Babai, West Rapti, Bagmati, Kamala, Kankai and Mechi Rivers, are fed by precipitation and groundwater. These rivers are perennial but with little flow during the dry season. Streams and rivulets originating mostly from the Chure hills make up the third category. These rivers rely on monsoon rains and are otherwise dry. The first and second category of rivers have a high potential for hydropower development.[2]

ELECTRICITY SECTOR OVERVIEW

The installed capacity of Nepal was 1,332.9 MW as of mid-2020, with large and small hydropower (SHP) providing 1,278.1 MW (96 per cent) of the total, thermal power, including diesel and multi-fuel power plants, providing 53.4 MW (4 per cent) and solar power 1.4 MW (less than 1 per cent) (Figure 1). Nearly 46 per cent (581.9 MW) of the installed capacity of hydropower in the country is owned by the Nepal Electricity Authority (NEA), while the remaining 54 per cent (696.2 MW), comprising mostly run-of-river SHP plants, is owned by independent power producers (IPPs).[5]

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



Source: NEA[5]

Electricity generation in the 2019/2020 fiscal year reached 6,012 GWh, provided almost exclusively by hydropower, with generation from other sources being negligible. Hydropower plants owned by the NEA provided 3,021 GWh (50 per cent) of this total, while those owned by IPPs provided an additional 2,991 GWh (50 per cent). While imports from India equalled 1,729 GWh, representing a nearly 39 per cent decline relative to the previous fiscal year, total electricity available in the grid reached 7,741 GWh, increasing slightly from the 7,551 GWh during the previous fiscal year (Figure 2).[2]

Figure 2. **Electricity Supply in Nepal in 2019/2020 (GWh)**

Source: NEA[5]

Electricity consumption during the 2019/2020 fiscal year equalled 6,422 GWh, while peak power demand reached 1,408 MW. Consumption was dominated by the domestic and industrial sectors, at 2,867 GWh and 2,286 GWh purchased, respectively. The nationwide rate of electricity access in Nepal was 90 per cent in 2020, but per-capita electricity consumption remains very low at 267 kWh per year.[6,7]

Transmission and distribution losses equalled over 15 per cent in 2019/2020, but showed a slight decrease relative to the previous fiscal year as a result of the continuous efforts by the NEA to improve the electricity grid. The national grid consisted of 78 circuit kilometres (ckm) of 400 kV lines, 178 ckm of 220 kV lines, 3,037 ckm of 132 kV lines and 514.5 ckm of 66 kV lines as of mid-2020. Total capacity of grid substations was 6,305 MVA. To enhance and expand transmission capacity, the Government of Nepal launched several initiatives, including study and construction of transmission lines of different voltages as well as of additional substations. As of mid-2020, 576 ckm of 400 kV lines, 584 ckm of 220 kV lines and 1,176 ckm of 132 kV transmission lines were under construction. The total lengths of distribution lines of 33 kV, 11 kV and 400/230 V were 5,552 ckm, 39,522 ckm and 122,117 ckm, respectively. In addition to the country's installed capacity, power is also being imported from India via 11 cross-border transmission lines at different voltages; five at 33 kV, five at 132 kV and one at 400 kV.[5,8]

Following the signing of the Electric Power Trade, Cross Border Transmission Interconnection and Grid Connectivity Agreement win India in 2014, the Joint Technical Team of Nepal and India formulated the Integrated Transmission Master Plan, paving the way for electricity exports from Nepal to India from power plants that are expected to become operational by 2035. In parallel, a domestic Transmission System Development Plan has been prepared by the Government of Nepal to account for the added capacity expected to come into operation by 2040.[9]

Ten years of internal conflict left their mark on the electricity sector of the country. Nepal faced a severe power crisis as planned projects were not commissioned on time. Despite having a very significant hydropower potential (83 GW of theoretical and 43 GW of economically feasible potential), Nepal has been importing electricity from India to meet its growing domestic demand.[6] The earthquake in April 2015 also severely affected the electricity system of the country, with at least 150 MW of hydropower installed capacity damaged. Due to the nature of the earthquake and the landslides it caused, mini- and micro-hydropower plants located in the mountainous regions were particularly affected, resulting in at least 45 MW of damaged capacity.[10] As of 2018, most of these plants were back in operation after having been non-functional for approximately 1–2 years. Furthermore, 219 new hydropower projects were under construction as of 2021 that would add some 8,321 MW of new capacity to the national grid within over the next five years. Surveys are being carried out to prepare feasibility studies for an additional 268 projects with a combined capacity of 24,982 MW.[11]

To expedite the development of the power sector in the country, on 18 February 2016 the Government of Nepal approved "The National Energy Crisis Management and Concept Paper for the Electricity Development Decade", which included a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of the power sector. Various reforms of the sector have been proposed, covering such aspects as the organizational, legal and administrative system, power purchase, electricity distribution, theft control and investment procedure, in order to accelerate private investments as well as to enhance the efficiency and effectiveness of public entities engaged in the power sector.[12] The proposals included simplifying working procedures in awarding licences, procuring private land or leasing Government land including forest land, establishment of Rastriya Prasharan Grid Company, Generation Company, steering committees at different levels to resolve disputes that may arise while implementing projects, setting electricity tariff rates for different types of projects (run-of-river, peaking run-of-river, storage and solar power plants) and mitigating foreign currency exchange risk. In order to increase energy security, provisions have been made to develop storage and alternate energy resources projects, including solar power and wind power plants.[8]

Key institutions operating in the power sector of Nepal include the Ministry of Energy, Water Resources and Irrigation (MoEWRI), the Department of Electricity Development (DoED), the Alternate Energy Promotion Centre (AEPC), the Investment Board of Nepal (IBN), the Nepal Electricity Authority (NEA), the Electricity Regulatory Commission (ERC) and IPPs. The MoEWRI, DoED, AEPC and IBN play facilitating roles in the power sector, while the ERC acts as the national power sector regulator. The state-owned NEA and IPPs are both responsible for the power generation sector, while the NEA is additionally responsible for most transmission, distribution, scheduling, dispatch and sales of electricity. The private sector has participated in the electricity market of Nepal since 1992, under the Hydropower Development Policy issued the same year. One large privately-owned distribution company, Butwal Power Company, supplies electricity to 50,000 consumers. In addition, there are many community-managed distribution schemes scattered across the country.[13]

Legislation regulating the power sector in Nepal is continuously refined based on experiences applying the Build-Own-Operate-Transfer (BOOT) model in power projects, international best practices and the emergence of new technologies. The Electricity Bill, 2020, recently submitted for parliamentary approval, includes mechanisms and procedures to enhance transparency, promote competition and minimize inefficiencies in the power sector in order to deliver reliable and secure electricity at affordable prices. Similarly, the National Water Resources policy approved on 13 July 2020 includes provisions to harmonize water use among various stakeholders at the national, provincial and local levels.[8]

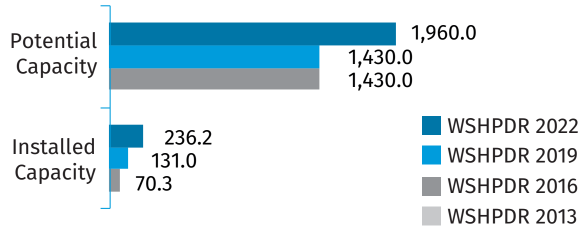
Electricity tariffs for domestic consumers in Nepal include 230 V single-phase low-voltage connections, 400 V three-phase low-voltage connections and 33/11 kV three-phase medium-voltage connections. Single-phase low-voltage tariffs vary according to monthly consumption (kWh/month) and connection amperage (5/15/30/60 A) and are composed of a minimum monthly charge and an energy consumption charge. In 2020, minimum monthly charges ranged between 30 NPR/month and 275 NPR/month (0.25-2.30 USD/month) and consumption charges ranged between 0 NPR/kWh (0 USD/kWh) for consumption under 10 kWh/month and 12 NPR/kWh (0.10 USD/kWh) for the highest consumption category.[5]

SMALL HYDROPOWER SECTOR OVERVIEW

Nepal generally adheres to the definition of SHP as hydropower plants with a capacity of up to 25 MW. However, it is not clearly defined in government policy or legal documents.

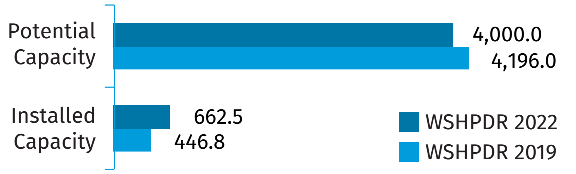
As of April 2021, the installed capacity of SHP up to 25 MW in Nepal was 662.5 MW from 85 plants, predominantly composed of plants with an installed capacity of up to 10 MW. The potential capacity of SHP up to 25 MW is estimated at approximately 4,000 MW, based on projects that have submitted licence applications as well as those on the Government's reserve list.[11] Relative to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity of SHP up to 25 MW in Nepal has increased by 48 per cent due to the construction of new SHP plants, while the estimated potential capacity decreased by 5 per cent, based on more accurate data (Figure 3).[14] No current data on the installed or potential capacity of SHP up to 10 MW is available (Figure 4).

Figure 3. **Small Hydropower Capacities up to 25 MW in the WSHPDR 2019/2022 in Nepal (MW)**



Source: DoED,[11] *WSHPDR 2019*[14]

Figure 4. **Small Hydropower Capacities up to 10 MW in the WSHPDR 2013/2016/2019 in Nepal (MW)**



Source: *WSHPDR 2019*,[14] *WSHPDR 2013*,[15] *WSHPDR 2016*[16]

The total number of SHP projects that have received generation licences stood at 159 as of April 2021, with a total proposed capacity of approximately 2,001 MW. Meanwhile, 14 projects totalling 125 MW had applied for a construction licence and 153 projects totalling 1,839 MW had been granted licences for the preparation of feasibility studies and environmental impact assessments. Finally, several additional SHP projects are currently under study.[11] The majority of existing and planned SHP capacity is connected to the national grid, but approximately 3,000 micro-hydropower plants with a total installed capacity of 35 MW are off-grid and provide power to rural and isolated areas.[17] Some recently commissioned SHP plants in Nepal are listed in Table 1, while several ongoing projects are listed in Table 2.

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

Name	*Location (River)*	*Capacity (MW)*	*Type of plant*	*Operator*	*Launch year*
Rawa Khola	Rawa Khola	3.00	Run-of-river	Rawa Energy Development Pvt Ltd	2020
Super Mai-A	Mai Khola	9.60	Run-of-river	Sagarmatha Jalbidhyut Company Pvt. Ltd.	2020
Super Mai Khola Cascade	Mai Khola	3.00	Run-of-river	Mai Khola Hydropower Pvt.Ltd.	2020
Ghalemdi Khola	Ghalemdi	5.00	Run-of-river	Ghalemdi Hydro Limited	2019
Kapadigad	Kapadigad	3.33	Run-of-river	Salmanidevi Hydropower Pvt Ltd	2019

Name	Location (River)	Capacity (MW)	Type of plant	Operator	Launch year
Solu	Solu Khola	23.50	Run-of-river	Upper Solu Hydroelectric Company Pvt Ltd	2019
Iwa Khola	Iwa Khola	9.90	Run-of-river	Rairang Hydropower Development Co Ltd	2019
Upper Khorunga	Khoranga Khola	7.50	Run-of-river	Terhathum Power Company Pvt. Ltd.	2019
Upper Naugad Gad	Naugad	8.00	Run-of-river	Api Power Company Ltd.	2019
Upper Mardi	Mardi	7.00	Run-of-river	United Idimardi and R.B. Hydropower Pvt Ltd	2019
Rudi Khola-B	Rudi Khola	6.60	Run-of-river	Bindhyabasini Hydropower Development Co. Pvt Ltd	2019
Padam Khola	Padam Khola	4.80	Run-of-river	Dolti Power Company P. Ltd	2019
Rudi A	Rudi Khola	8.80	Run-of-river	Bindhabasini Hydropower Development Company Pvt.Ltd	2018
Bagmati Nadi	Bagmati	22.00	Run-of-river	Mandu Hydropower Pvt. Ltd.	2018
Theule Khola	Theule	1.50	Run-of-river	Barahi Hydropower Pvt Ltd	2018
Super Mai	Mai Khola	7.80	Run-of-river	Supermai Hydropower Pvt.Ltd.	2018
Madkyu Khola	Madkyu	13.00	Run-of-river	Silkes Hydropower Pvt.Ltd	2017
Chake Khola	Chake Khola	2.83	Run-of-river	Garjang Upatyaka HP Company Limited	2017
Dwari Khola	Dwari	3.75	Run-of-river	Bhugol Energy Development Company Pvt Ltd	2017
Molun Khola	Molun	7.00	Run-of-river	Molun Hydropower Co. Pvt. Ltd	2017

Source: DoED[11]

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

Name	Location (River)	Capacity (MW)	Type of plant	Developer
Langdi Khola	Langdi	3.26	Run-of-river	Ujyalo Nepal Hydro Pvt. Ltd.
Upper Daraudi	Daraudi	9.20	Run-of-river	Green Gorkha Energy Limited
Upper Ingwa Khola	Ingwa	9.70	Run-of-river	Ingwa Hydopower Pvt. Ltd.,
Setikhola	Seti Khola	22.00	Run-of-river	Setikhola Hydropower Pvt.Ltd.
Mewa Khola	Mewa Khola	23.00	Run-of-river	Union Mewa Hydro ltd

Source: DoED[11]

Note: Data as of 2021.

In general, Nepal views hydropower development as an important means for enabling economic growth and human development, as well as for overcoming the imbalance between demand and supply and keeping pace with the growth of annual demand. There is huge potential for the development of SHP projects in Nepal with an attractive rate of return. Several SHP projects available for investment are displayed in Table 3.

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

Name	Location	Capacity (MW)	Plant type	Developer
Hidi Khola	Lamjung	6.80	Run-of-river	North Summit Hydro Pvt. Ltd.
Upper Irkhuwa	Bhojpur	14.50	Run-of-river	Arati Power Company Ltd.
Middle Trishuli Ganga	Nuwakot	19.41	Run-of-river	Perfect Energy Development Pvt. Ltd
Mewa Khola	Taplejung	23.00	Run-of-river	Union Mewa Hydro Ltd.
Madame Khola	Kaski	24.00	Run-of-river	Madame Khola Hydropower Pvt. Ltd.

Source: IPPAN[18]

Note: Data as of 2021.

RENEWABLE ENERGY POLICY

In 2011, the Government of Nepal launched the National Rural and Renewable Energy Programme (NRREP), which aimed to scale up energy access in rural areas through renewable energy sources (RES). In 2016, the Government of Nepal adopted the Renewable Energy Subsidy Policy, which aims to foster the development of the renewable energy sector and support low-income households in using renewable energy technologies through subsidies. In particular, subsidies for micro- and mini-hydropower facilities range from NPR 20,000 to NPR 125,000 (USD 167 to USD 1,042) per kW for generation and from NPR 28,000 to NPR 35,500 (USD 233 to USD 296) per household for distribution.[19]

As of the end of the fiscal year 2019/2020, approximately 10 per cent of the total population had access to electricity from RES, while 36 per cent of the population were using clean renewable energy for various purposes.[6]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

The Electricity Act (1992), the Electricity Regulation (1993) and the Water Resources Act (1992) are the key legal documents that paved the entry of the private sector into the development of power projects. A licence is required for conducting preliminary investigations for projects of 1 MW capacity or more. For projects of below 1 MW capacity, this requirement is waived by provisions contained in the Electricity Act (1992), provided the project is registered with the District Water Resources Committee and forwarded to the DoED.

There is a two-stage licensing system. The first stage is a survey licence issued for a maximum of five years to carry out feasibility and environmental studies. The second stage is a generation licence granted for a set term for the construction and operation of a power plant. At the end of the term, the licensee is required to transfer the project to state ownership free of charge and in a good operating condition. The Hydropower Development Policy (2001), aiming to improve nationwide electricity access through the development of affordable and efficient hydropower, updated the duration of generation licences to 35 years for domestic projects and 30 years for export-oriented projects.[20,21]

COST OF SMALL HYDROPOWER DEVELOPMENT

The cost of SHP development in Nepal includes the costs of civil engineering, metal works, plant machinery, installation of transmission lines and switch yard, land purchase and development, purchase/operation of vehicles, environment and social mitigation, project supervision, insurance and other miscellaneous costs. The average cost of development per installed MW is approximately NPR 200 million (USD 1.67 million), with a breakdown of costs provided in Table 4.[8]

Table 4. **Average Costs of Small Hydropower Development in Nepal**

Particulars	*Cost per MW in (NPR (USD)*	*Share of total cost*
Licence and study cost	5,000,000 (42,000)	3%
Construction/installation cost	140,000,000 (1,170,000)	70%
Land, infrastructure and management, social mitigation, insurance	20,000,000 (170,000)	10%
Contingency	10,000,000 (83,000)	5%
Finance cost (IDC)	25,000,000 (210,000)	13%
Total	**200,000,000 (1,670,000)**	**100%**

Source: Bhetuwal & Poudel[8]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

Nepal has abundant opportunities for financing of SHP projects as this sector is given special priority in the country. The Ministry of Industry, Commerce and Supply, the MoEWRI and the Office of IBN are several of the many government institutions involved in facilitating foreign and domestic investment in SHP. Domestic or foreign investors can finance SHP projects and mixed foreign-domestic financing of projects is also possible. However, domestic investment is prevalent. Loans raised for SHP projects typically come from banks/financial institutions, while the equity is raised by the promoter through public shares. In general, the debt-to-equity ratio is maintained at 70:30. The payback period from SHP operation is typically 7–10 years, while the loan repayment period is typically set at 8–12 years and begins at the start of commercial operation.

In order to gain access to domestic financing options, investors must typically conclude a power purchase agreement (PPA) with the NEA. The PPA electricity purchase rate set by NEA for run-of-river SHP projects is as follows:

- Energy generated during the rainy season (June to November) must reach at least 70 per cent of theoretical generation capacity of the plant and is purchased at 4.8 NPR/kWh (0.04 USD/kWh);
- Energy generated during the dry season (December to May) must reach at least 30 per cent of theoretical generation capacity of the plant and is purchased at 8.4 NPR/kWh (0.07 USD/kWh);
- The given rate has a 3 per cent simple escalation for a period of eight years.[8]

Additionally, the Government of Nepal provides various tax exemptions and other incentives for SHP developers. These include a 1 per cent cap on customs duties, a 100 per cent income tax exemption for the first 10 years of operation and thereafter a 50 per cent income tax exemption for another 5 years and a value-added tax (VAT) exemption on the purchase of electromechanical equipment and parts for SHP plants.[8]

At the same time, the developer is obligated to pay royalties to the Government for operation of SHP plants. The royalty mechanism applies to SHP plants with an installed capacity over 1 MW and includes an annual capacity royalty of 100 NPR/kW (0.85 USD/kW) and a generation royalty of 2 per cent of the sale price per kWh sold for the first 15 years of operation as well as a capacity royalty of 1,000 NPR/kW (8.51 USD/kW) and generation royalty of 10 per cent per kWh sold for every subsequent year of operation.[8]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

The impact of the climate crisis on SHP generation and development in Nepal include wider disparity between seasonal distribution of rainfall and runoff. During the winter season, projected decreases in precipitation and runoff are likely to lead to reductions in hydropower generation. With electricity demand likewise peaking during the winter, increased load shedding and electricity imports from India will likely be necessary. During the rainy season, an increase in runoff and extreme rainfall is expected according to climate models. With the overwhelming majority of SHP plants in Nepal being of the run-of-river type, floods and heavy sediment inflow are likely to cause damage to hydropower structures and increase the operation and maintenance cost of SHP plants in particular.

Climate policy in Nepal with regard to SHP must focus on adaptation measures, including promoting structural designs for SHP plants that account for expected extreme weather impacts. Riverside power facilities should be more robust than has been typically practiced in recent development to cope with future climate-induced flooding. Additionally, SHP plants need to be designed to better cope with low flow and be able to continue generating electricity even under drought conditions. Additional adaptation measures should include careful site selection for SHP in locations less vulnerable to extreme weather impacts, better insurance policies and the development of an early warning system for floods and landslides to reduce damage to SHP structures.[8]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

While there has been extensive growth of SHP in Nepal over the past 50 years, there remain several limiting factors to SHP development. Some of the principal barriers include:

- Lack of clear and supportive policies and a regulatory framework;
- Political instability;
- Limitations on bank financing: unattractive loan duration and interest rates as banks are unable to raise long-term borrowings, inability to hedge the exchange risk as lending is in USD but the income stream is in NPR;
- Ineffective licensing procedure;
- No single agency fully empowered to serve the SHP sector;
- Poor or non-existent access to infrastructure or power evacuation lines;
- The burdensome procedure of carrying out an environmental impact assessment may lead to delays in the implementation of projects;
- Additional financial burden on NEA during certain periods of the year resulting from underutilization of its own power plants while being forced to absorb power from SHP plants due to take-or-pay PPAs;
- Limited domestic demand; only one off-taker, NEA, often unwilling to sign PPAs;
- Issues with legal enforcement of contracts;
- High sedimentation rate requiring large desanders or additional maintenance to repair turbines;
- Inconsistent policies;
- Low load factors of SHP plants and their inability to deliver energy during the dry season;
- Absence of integrated river basin plans;
- Growing expectations of local people towards hydropower projects due to the compensation amount for the land acquired by the developers being 4 to 10 times higher than the market price;
- Weak geology requiring more investment in the slope protection and tunnelling;
- Hydrological uncertainties due to climate change.

At the same time, several enabling factors for further SHP development in Nepal do exist, including the following:

- Availability of skilled manpower for the design and construction of SHP projects;
- Availability of domestic financing;
- Availability of multiple projects in various stages of planning requiring additional investment;
- Incentives and tax exemptions for developers.

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Pakistan

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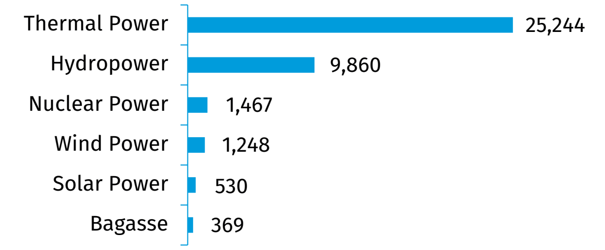
KEY FACTS

Population	215,250,000 (2021)[1]
Area	803,940 km^2 [2]
Topography	Pakistan exhibits a blend of landscapes varying from plains to deserts, forests, hills, plateaus, coastal areas of the Arabian Sea in the south and the mountains of Karakoram and Himalayan ranges in the north. The world's second and ninth highest peaks, K-2 (8,611 metres) and Nanga Parbat (8,126 metres) are located in the northernmost parts of Pakistan.[3]
Climate	The climate is dry and hot in plain lands, becoming progressively cooler towards the north-eastern highlands. In Islamabad, the capital city, hot season begins in March and by June temperatures may reach up to 46 °C, while the cold season lasts from December to February, when the temperature may drop below -3 °C. In the northernmost parts of the country, winter temperatures may fall below -10 °C.[2]
Climate Change	The foreseen effects of climate change in Pakistan include increased variability of monsoons, the likely receding of the Hindu Kush-Karakoram-Himalayan glaciers due to temperature increase and carbon soot deposits from transboundary pollution sources, which will threaten water inflows into the Indus River system. Other risks include severe water shortages, particularly in arid and semi-arid regions, decreasing forest cover and increased level of saline water in the Indus delta. In the last 50 years, the annual mean temperature in Pakistan has increased by roughly 0.5 °C and variability in annual precipitation has increased. The number of heatwave days per year has increased nearly fivefold in the last 30 years. The sea level along the Karachi coast has risen by approximately 10 cm in the last century and is expected to rise by a further 60 cm by the end of the century. By the end of this century, the annual mean temperature in Pakistan is expected to rise by 3-5 °C for the central global emissions scenario, while higher global emissions may yield a rise of 4-6 °C. Average annual rainfall is not expected to have a significant long-term trend, but is expected to exhibit large interannual variability, an example of which is a cloudburst that occurred in 2001 resulting in 620 mm of rainfall recorded over 12 hours in Islamabad.[4]
Rain Pattern	The distribution of rainfall in Pakistan varies greatly, mostly associated with monsoon winds and the western disturbances. Precipitation is not continuous throughout the year and also varies from year to year. Between June and September, the monsoon provides an average rainfall of approximately 38 mm in the river basins and up to approximately 150 mm in the north. In some areas, high volumes of rainfall can cause floods, while in desert areas low rainfall can cause droughts.[3,5]
Hydrology	The main surface water resources of Pakistan are represented by the Indus River and its tributaries. The Indus River has a total length of 3,780 km, with a drainage basin of approximately 1,165,000 km^2. Its main tributaries are the Jhelum, Chenab, Ravi, Beas and Sutlej. Most groundwater resources exist in the Indus Plain, extending from the Himalayan foothills to the Arabian Sea, and are stored in alluvial deposits. The plain is approximately 1,600 km long, covers 210,000 km^2 and has an extensive unconfined aquifer, which is fast becoming the supplemental source of water for irrigation. Mean annual availability of surface and groundwater is approximately 170,000 million m^3 and 71,000 million m^3, respectively.[6]

ELECTRICITY SECTOR OVERVIEW

In mid-2020, the total installed capacity of Pakistan under the control of the National Transmission and Distribution Company (NTDC) was 38,719 MW. Thermal power accounted for approximately 64 per cent of total installed capacity, hydropower for 26 per cent, nuclear power for 4 per cent, wind power for 3 per cent, solar power for slightly more than 1 per cent and biomass for 1 per cent (Figure 1).[7] Hydropower and thermal power sources have been used for much of the country's history, with plants being mainly located in the northern parts of the country and a few in the plains. The generation of electricity from nuclear power, solar power, wind power and other alternative sources has begun rather recently. As a result, the number and capacities of these plants are smaller than those of thermal and hydropower plants.[7]

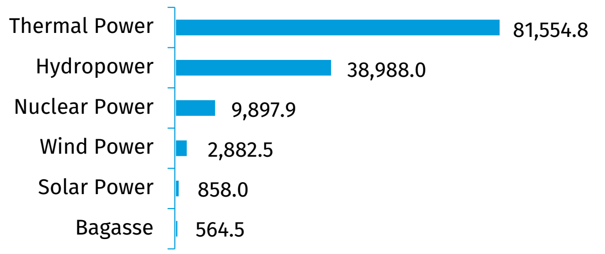
Figure 1. **Installed Electricity Capacity by Source in Pakistan in 2020 (MW)**



Source: NEPRA[7]

In terms of electricity generation, out of the total of 134,746 GWh generated in 2019–2020, almost 61 per cent came from thermal power, 29 per cent from hydropower, 7 per cent from nuclear power, 2 per cent from wind power and less than 1 per cent from bagasse and solar power each (Figure 2). An additional 514 GWh was imported from Iran.[7]

Figure 2. **Annual Electricity Generation by Source in Pakistan in 2019–2020 (GWh)**



Source: NEPRA[7]

At the end of 2020, there were over 575,000 kilometres of transmission lines and 999 grid stations of various capacities in service.[8] The total number of electricity consumers was 32.9 million and the total number of villages electrified was 157,203.[7] In 2019, approximately 74 per cent of the population of Pakistan had access to electricity.[9]

Prior to 1998, there were two vertically integrated utilities, the Karachi Electric Supply Company (KESC), which served the Karachi area, and the Pakistan Water and Power Development Authority (WAPDA), which served the rest of the country and was the largest public power generating company owning more than 59 per cent of the country's generating capacity and serving the majority of consumers. The power sector was restructured in 1998 with the creation of PEPCO (Pakistan Electric Power Company). WAPDA's power division was restructured into distinct corporate entities comprising four generation companies (GENCOs), 10 distribution companies (DISCOs) and the National Transmission and Distribution Company (NTDC). A small share of power distribution has been undertaken by K-Electric (formerly KESC) serving electric power in Karachi, the biggest city of Pakistan.[10]

The National Electric Power Regulatory Authority (NEPRA) is the country's sole authority that determines and fixes the tariffs for all types of generating plants and electricity consumers (domestic, commercial and industrial). Peak and off-peak tariffs are charged to industrial consumers and now to domestic consumers as well. The average household electricity tariff paid in Pakistan in 2020 was approximately 0.14 USD/kWh.[7]

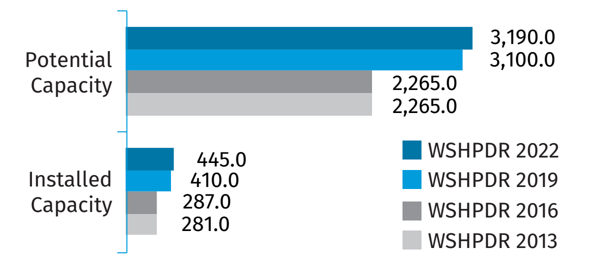
In Pakistan, a large part of the current decade was plagued with excessive load-shedding due to non-availability of sufficient affordable generation capacity and inefficient transmission and distribution services. With the introduction of a substantial amount of generation capacity during the last few years, the availability of electricity has improved significantly but the cost of electricity for end-consumers has increased owing to various reasons, such as high transmission and distribution losses, low recovery, circular debt, huge capacity payments, currency devaluation, fuel cost and underutilization of efficient power plants.[10]

SMALL HYDROPOWER SECTOR OVERVIEW

In Pakistan, two types of classification of small hydropower (SHP) exist. Under the Renewable Energy Policy of 2006, SHP plants were classified as those under or equal to 50 MW. In 2015, following NEPRA's determination of the upfront tariff for SHP projects, the definition of 25 MW and below was introduced.

In this chapter, based on the above categorization, the benchmark for SHP is taken as 50 MW. The installed capacity of SHP according to this definition was 445 MW as of 2020, generating 1,900 GWh annually. Total estimated potential is approximately 3,190 MW, indicating that some 14 per cent of the country's SHP potential has been developed.[11,12,13,14,15,16] Compared to the results of the *World Small Hydropower Development Report (WSHPDR) 2019*, installed capacity increased by nearly 9 per cent, while estimated potential capacity increased by approximately 3 per cent (Figure 3). The increase in installed capacity was due to several new SHP projects commissioned in recent years.

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



Source: AEDB,[11] WAPDA,[12] Qureshi & Akıntuğ,[13] PPIB,[14] SMEC-EGC,[15] *WSHPDR 2013*,[16] *WSHPDR 2016*,[17] *WSHPDR 2019*[18]

Note: Data for SHP up to 50 MW.

Of the total installed hydropower capacity of Pakistan, SHP accounts for almost 5 per cent, while the SHP potential is approximately 5 per cent of the total hydropower potential (approximately 60,000 MW).[13] The north of Pakistan is rich in hydropower resources. Numerous SHP projects have already been developed (Table 1) and many are under implementation (Table 2) or have been identified in preliminary hydropower potential studies of various river basins (Table 3). The province of Gilgit-Baltistan has the greatest installed capacity and the largest potential, while in Baluchistan the potential is negligible due to the region's very low rainfall.

The major part of development of small and micro-hydropower in Pakistan is being undertaken by the Pakhtunkhwa Energy Development Organization (PEDO), Punjab Power Development Board (PPDB), Alternative Energy Development Board (AEDB) and Pakistan Council of Renewable Energy Technologies (PCRET). PEDO has recently completed a programme of development of 356 off-grid micro-hydropower plants with a total capacity of 35 MW in the high mountainous districts of the Pakhtunkhwa province. A similar programme to develop a further 672 micro-hydropower plants on canal falls (53 MW), with the assistance of the Asian Development Bank (ADB), has been initiated.

PCRET is a pioneering agency in introducing the micro-hydropower technology in Pakistan and serves as the national focal point for the development and dissemination of renewable energy technologies in the country. In particular, PCRET has installed in northern areas more than 560 micro-hydropower plants (less than 200 kW) with a combined capacity of approximately 9 MW to meet the energy demand of more than 80,000 households. PCRET has also developed, installed and tested a cross-flow turbine of 10–50 kW. A China–Pakistan Joint Research Center for SHP and Hydropower Support Workshop have also been established in Islamabad and Peshawar, respectively. Further, the National Hydropower Plant Quality Control and Electromechanical Equipment Testing Center as well as the Hydropower Power Plant Electromechanical Equipment and Allied Accessories Manufacturing Facility are going to be established in Islamabad.

PPDB is encouraging development of SHP projects in the individual power producer (IPP) and captive modes. Recently, PPDB issued a letter of interest for 17 SHP sites with a combined installed capacity of 129 MW for development in the IPP mode. These projects are in different stages of development, overall, their pace of development is slow due to a non-supportive response of the Federal Ministry of Energy and its associated departments. Considering the hurdles in development of SHP projects for the national grid, PPDB has initiated a project for the development in the captive mode of projects of less than 2 MW to supply generated electricity for the self-use of small enterprises with the vision to enhance the development of small industries and increase rural employment. In this regard, the Captive Guidelines for SHP projects have been approved by the Board. As the first phase of the project, the Board has allowed the initiation of 10 SHP projects with an aggregate capacity of 13.55 MW in the captive mode.

The Agha Khan Rural Support Programme (AKRSP) has installed micro- and mini-hydropower plants at Chitral and other places in Gilgit Baltistan.[19] It has launched a strategy programme for priority valleys, with a total of nine projects initiated in 2016. Out of these, six projects have been completed (four in 2016 and two in 2017) and three projects remain under construction (two in Chitral, one in Gilgit). The Immit SHP plant of 300 kW was planned to be completed by the end of 2021 and two projects in Chitral were to be completed in 2018. In addition, two new SHP projects were to be initiated in the last quarter of 2017, with plans for further project development conditional on funding availability. The Swiss Agency for Development and Cooperation (SDC) had funding commitments for two projects and those were completed in 2016. Currently there is no funding availability with SDC for new SHP projects. However, there is great demand and potential for investment in SHP in the program area. All of the 13 SHP plants (including nine in 2016, two in 2017 and two in 2018) directly benefit 49,500 beneficiaries in the region.

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

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Plant type*	*Operator*	*Launch year*
Jhing I	AJK	14.4	High	Run-of-river	AJK Government	2021
DaralKhwar	Khyber PakhtunKhwa	36.0	High	Run-of-river	KPK Government	2021
Ranolia	Khyber PakhtunKhwa	17.0	High	Run-of-river	KPK Government	2021
Naltar V	Gilgit Baltistan	14.0	High	Run-of-river	Gilgit Baltistan Government	2017
Rasul UJC Hydro	Punjab	35.0	Low	Run-of-river	Punjab Government	1952/ 2015
Jabban	Khyber PakhtunKhwa	22.0	High	Run-of-river	WAPDA	1952/ 2013
Satpara	Gilgit Baltistan	17.4	High	Reservoir	WAPDA	2013
Jagran I	AJK	30.4	High	Run-of-river	AJK Government	2011
Pehur	Khyber PakhtunKhwa	18.0	High	Run-of-river	KPK Government	2009
Naltar IV	Gilgit Baltistan	18.0	High	Run-of-river	Gilgit Baltistan	2007
Gilgit	Gilgit-Baltistan	10.6	High	Run-of-river	Gilgit Baltistan Government	1998

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Plant type*	*Operator*	*Launch year*
Nandipur	Punjab	13.8	High	Run-of-river	WAPDA	1963
Shadiwal	Punjab	13.5	Low	Run-of-river	WAPDA	1961
Chicho ki Milan	Punjab	13.2	Low	Run-of-river	WAPDA	1959
Dargai	Khyber Pakhtunkhwa	20.0	High	Run-of-river	WAPDA	1952

Source: WAPDA,[12] AJK PDO,[20] PEDO[21]

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

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Plant type*	*Developer*	*Planned launch year*	*Stage of development*
Jabori	Khyber Pakhtunkhwa	10.2	High	Run-of-river	KPK Government	2022	Under construction
Jagran II	AJK	48.0	High	Run-of-river	AJK Government	2022	Under construction
Koto	Khyber Pakhtunkhwa	40.8	High	Run-of-river	KPK Government	2022	Under construction
Kurram Tangi Stage-I	Khyber Pakhtunkhwa	18.9	High	Run-of-river	WAPDA	2022	Under construction
Nagdar	AJK	35.0	High	Run-of-river	AJK Government	2022	Under construction

Source: WAPDA,[12] AJK PDO,[20] PEDO[21]

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

Name	*Location*	*Potential capacity (MW)*	*Head (m)*	*Type of site (new/refurbishment)*
BS Link Tail	Kasur, BS-1	10.5	3	New
Murree	Murree	12.0	136	New
Soan	DohkMarkhel	35.0	10	New

Source: Government of Punjab[22]

RENEWABLE ENERGY POLICY

Although various energy policies implemented by Pakistan between 1985 and 2002 stressed the need for employing renewable energy resources, none provided a framework for the implementation of such projects. A clear road map for the development of domestic renewable resources was virtually non-existent as these policies failed to create private sector confidence and attract investment. In 2002, the Power Policy was adopted, which encouraged the use of local resources, including renewable energy.[23] The policy aimed to develop approximately 500 MW of renewable generation capacity (excluding hydropower) by 2015 and 1,000 MW by 2020.

The Alternative Energy Development Board (AEDB) was established in May 2003 with the main objective of facilitating, promoting and encouraging development of renewable energy in Pakistan. In 2006, AEDB introduced the Policy for Development of Renewable Energy for Power Generation, which became the first policy aiming to promote renewable energy projects in Pakistan. The policy set the goal to achieve a 10 per cent share of renewable energy in the country's energy mix by 2015, specifically focusing on solar power, wind power and SHP projects.[24] The policy aims to harmonize the work of various Government bodies in relation to alternative and renewable energy, introduce incentives to attract investment, optimize the impact of alternative and renewable energy technologies in less developed areas, increase related institutional and technical capacities, promote research and development and create a local base for manufacturing alternative and renewable energy technologies. The policy also set the goal to increase per capita energy consumption while promoting environmental protection and awareness, especially in remote and rural areas where poverty can be alleviated and the burden on women collecting biomass fuel can be reduced. Specific incentives for IPPs of alternative and renewable energy include a simplified generation licensing procedure, simplified land and site access, guaranteed purchase of all power and payment and facilitated acquisition of carbon credits. Since the adoption of the policy, the share of renewable energy in the country's energy mix grew substantially, having reached some 31 per cent by mid-2020, although the sector remained dominated by thermal power.

In April 2015, the Power Generation Policy 2015 was published by the Private Power and Infrastructure Board (PPIB) after its approval by the Council of Common Interests. The main objectives of the policy are to provide sufficient power generation capacity at the least cost, encourage and ensure exploitation of domestic resources, ensure that the interests of all stakeholders are taken into account to create a win-win situation for all and be attuned to safeguarding the environment. The policy deals with private projects, public power projects where required by the project sponsor, public-private partnership (PPP) projects and projects developed by the public sector and subsequently divested.[25]

More recently, the Government released a draft policy on Alternative and Renewable Energy 2019. The policy has an expanded scope encompassing all major alternative and renewable energy sources, competitive procurement and addresses such areas as distributed generation systems, off-grid solutions, B2B methodologies and rural energy services. It carries forward most of the liberal and attractive incentives of the 2006 Renewable Energy Policy to maintain the investors' confidence and places greater emphasis on the accelerated growth of grid-connected projects as well as a programmatic development of a distributed alternative and renewable energy generation market on more competitive terms. Further, the policy sets the target to increase on-grid renewable energy generation capacity by at least 20 per cent by 2025 and at least 30 per cent by 2030. SHP projects (less than 50 MW) are not covered under this Policy. A separate policy is under consideration for SHP and until then SHP will be developed under the Power Policy 2015

Recently the Government of Pakistan has approved the National Electricity Policy 2021, which has set the goal for sustainable renewable energy market development, with a dedicated gradual increase of the renewable energy share in the generation mix. As for the Indicative Generation Capacity Expansion Plan (IGCEP), the goal is to strengthen the energy security of the country by increasing the projects based on domestic energy and maximizing the renewable energy component. These goals, if seriously implemented, will help make development of SHP projects easier. Eventually, more efforts will be channelled to developing SHP projects in the mountainous regions towards the north of the country, especially in off-grid areas.

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

The Government of Pakistan as well as selected provincial governments (AJ&K, KP, Punjab and BG) are promoting hydropower development, including SHP, in order to increase the share of hydropower share in the overall energy mix. The provincial Government of Punjab has initiated the approval process of guidelines for development of SHP projects in the captive mode.

To promote private investment in SHP, in September 2017 a facilitation agreement was signed by PPIB and the Government of Azad Jammu and Kashmir. The parties agreed to cooperation and facilitation in setting up private hydropower power projects. Through this arrangement, a tripartite letter of support will be issued to project sponsors and developers and PPIB will facilitate them in establishing private power projects and related infrastructure through signing an implementation agreement and issuing a government guarantee under the provisions of the Power Generation Policy 2015. This initiative is expected to attract and encourage potential investors in developing small to medium-size hydropower projects in the provinces and further augment generation capacities. Earlier, PPIB had already signed a facilitation agreement with the Energy Department of the Government of Khyber Pakhtunkhwa and the Energy Department of the Government of Punjab.

According to NEPRA, comparatively small capital investment and short gestation periods are required to complete these projects. NEPRA has undertaken measures to simplify the investment process for small investors, including the introduction of an upfront tariff. The tariff provides certainty to the potential investors, allows for fast-tracking the development of commercially attractive SHP sites and ensures material risk coverage to the investor. The economic attractiveness of the upfront tariff was further enhanced with the tariff being adjusted for each site depending upon the plant factor.[26] There are three modes of tariffication based upon NEPRA's Competitive Tariff Regulations: cost, tariff and upfront tariff. NEPRA approved a maximum of PKR 13.029 (USD 0.13) per unit for the upfront tariff for SHP projects up to 25 MW under Section 31 (4) of the Regulation of Generation, Transmission and Distribution of Electric Power Act 1997.[27]

COST OF SMALL HYDROPOWER DEVELOPMENT

The average cost of high-head projects is USD 0.8–2 million per MW and for low-head projects the cost is approximately 1.5–USD 4.5 million per MW.[28] Costs in the region of Khyber Pakhtunkhwa are within the range of USD 1.2–2.7 million per MW.[12] The electromechanical equipment is mainly imported, which affects the cost.

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

The State Bank of Pakistan has initiated a financing scheme for renewable energy projects from 1 MW to 50 MW by providing financing at a 6 per cent interest rate.[29] Initially SHP projects were not included in this scheme, but NEPRA has requested the Government and the State Bank to include SHP in the renewable energy projects list. Further funds from the Clean Development Mechanism (CDM) as well as other funding opportunities associated with efforts to reduce greenhouse gas emissions can be utilized for the development of SHP projects.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

The recent changes in the rainfall pattern and intensity can have serious effects on SHP. Cloudbursts can result in flash floods, causing erosion of riverbanks and inflicting serious damage on SHP infrastructure. Many such incidents have been observed in the northern mountainous regions of Pakistan.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The future of SHP development in Pakistan is promising as abundant potential is available in the northern hilly areas, on canal falls and dams in the plains. The Government has devised policies for the development of renewable energy sources including SHP, which is the cheapest source of renewable energy. Nonetheless, a number of factors limiting SHP development in the country persist, including the following:

- Certain federal departments create administrative hurdles to SHP projects. The required consent from these departments, when not provided, block the development of projects;
- The involvement of a large number of institutions and departments and lack of coordination among them, as a result of which projects might take much longer to approve;
- The limited availability of financing and continuity of supply of funds for public sector projects;
- Higher cost of projects due to foreign components;
- Little interest from local manufacturers to develop low-cost electrical and mechanical equipment for SHP plants;
- Risks involved in SHP projects (including hydrology-related ones) can deter developers;
- Gilgit-Baltistan province has a significant large, medium and small hydropower potential; however, its population density and power demand are very low. Moreover, connecting it to the national grid requires very long transmission lines, which makes the development of the available potential unfeasible;
- Limited sustainability of the mini- and micro-hydropower projects developed for off-grid communities in terms of operation and maintenance.

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

- Significant potential remaining undeveloped;
- A number of programmes aimed at developing SHP projects in the country;
- The Government of Pakistan as well as selected provincial governments aim to increase the hydropower share in the overall energy mix;
- Need for electricity access, particularly in remote areas of the country.

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Sri Lanka

Danila Podobed, International Center on Small Hydro Power (ICSHP)

KEY FACTS

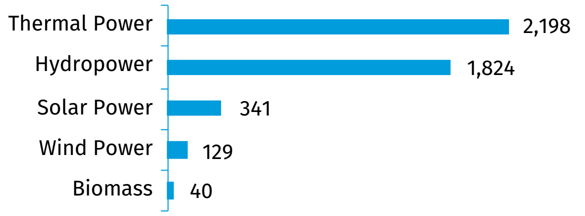
Population	21,919,000 (2020)[1]
Area	65,610 km^2 [2]
Topography	The island of Sri Lanka consists of three topographic zones: the plains, the coastal belt and the Central Highlands. The plains compose much of the island's surface, with elevation ranging between 30 and 200 metres above sea level. The coastal belt lies at roughly 30 metres above sea level and consists of sandy beaches punctuated by coastal lagoons. The Central Highlands rise in the south-central part of the country and include high central ridges, plateaus and hills ranging between 400 and 2,000 metres above sea level. The highest point in the country is Pidurutalagala at 2,524 metres.[3]
Climate	The mean annual temperature in Sri Lanka ranges from 26 °C to 28 °C. At Nuwar Eliya at 1,800 metres above sea level the mean temperature is 16 °C. In parts of the Central Highlands, daily extremes range from a high of 37 °C to a low of below 0 °C. The coldest month of the year is January while the hottest month is May.[3]
Climate Change	Between 1961 and 2000, a trend of increase in maximum annual temperatures by up to 0.046 °C has been observed across most observation stations in Sri Lanka. Climate change projections predict a rise in summer monthly temperature of 1.1–2.4 °C by 2100, relative to the 1961–1990 baseline period.[4]
Rain Pattern	Annual rainfall in Sri Lanka is spread over two monsoon seasons and two inter-monsoon seasons. The country receives an average of 1,860 mm of rainfall annually, with variation from 5,500 mm in the central hill region to 950 mm in the coastal plains. Overall, the south-western part of Sri Lanka receives substantially more rainfall than the northern, north-central and eastern regions of the country.[5]
Hydrology	There are 103 rivers in Sri Lanka, with most originating in the Central Highlands and flowing out into the Indian Ocean. The longest river in the country is the Mahaweli River at 330 kilometres, while the Aravi Aru River is the second-longest, at 220 kilometres. There are no natural lakes in Sri Lanka, but many large and small-scale manmade reservoirs have been constructed for electricity generation and irrigation purposes, with some up to 2,000 years old.[6,7]

ELECTRICITY SECTOR OVERVIEW

The total installed electricity capacity of Sri Lanka in 2019 was approximately 4,531 MW, of which thermal power provided 2,198 MW (49 per cent), hydropower provided 1,824 MW (40 per cent), solar power provided 341 MW (8 per cent), wind power provided 129 MW (3 per cent) and biomass provided 40 MW (less than 1 per cent) (Figure 1).[8] By 2020, wind power capacity in the country had expanded substantially to 252 MW, while biomass capacity increased to 54 MW.[9]

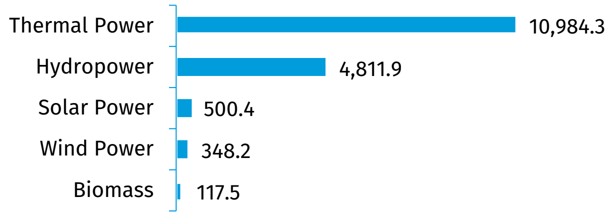
Total electricity generation in 2019 was 16,762.3 GWh, with thermal power accounting for 10,984.3 GWh (nearly 66 per cent), hydropower accounting for 4,811.9 GWh (29 per cent), solar power accounting for 500.4 GWh (3 per cent), wind power accounting for 348.2 GWh (2 per cent) and biomass accounting for 117.5 GWh (less than 1 per cent) (Figure 2). Transmission and distribution losses accounted for 1,372 GWh.[8]

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



Source: SEA[8]

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



Source: SEA[8]

Access to electricity in Sri Lanka was 100 per cent as of 2020.[10] Electricity consumption in 2019 amounted to 14,769.6 GWh, with the residential sector accounting for 5,523.7 GWh (37 per cent), industrial sector for 4,709.4 GWh (32 per cent), the commercial sector for 4,305.1 GWh (29 per cent) and the remaining 231.4 GWh (2 per cent) being accounted for by agriculture, street lighting and religious institutions. Transmission and distribution losses accounted for 1,372.0 GWh, while own use by producers accounted for 649.1 GWh.[8]

The state-owned company Ceylon Electricity Board (CEB) is the largest electricity producer in the country which owns the largest share of generating capacity as well as the transmission, distribution and retail sales of electricity. The Lanka Electricity Company (LECO) is a smaller company engaged in the distribution of electricity purchased from CEB to end users.[11,12]

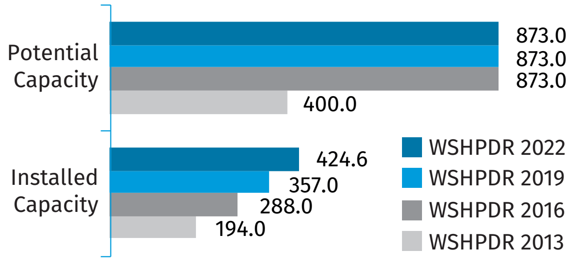
Electricity tariffs in Sri Lanka are set by the Public Utilities Commission of Sri Lanka (PUCSL), the economic, technical and safety regulator of the electricity sector in the country.[13] End user electricity tariffs have not changed since 2014, and range from 2.5 LKR/kWh to 45.0 LKR/kWh (0.007–0.130 USD/kWh) for residential users, based on monthly consumption volumes, and from 1.9 LKR/kWh to 26.6 LKR/kWh (0.005–0.074 USD/kWh) for non-residential users, with certain users charged by consumption volume and others based on peak, daytime and off-peak time of use (ToU) intervals. ToU tariffs are also optionally available for residential customers and range from 13.0 LKR/kWh to 54.0 LKR/kWh (0.036–0.150 USD/kWh).[14]

SMALL HYDROPOWER SECTOR OVERVIEW

Small hydropower (SHP) is defined in Sri Lanka as hydropower plants with an installed capacity of up to 10 MW and is additionally classified as a new renewable energy (NRE) resource, a category which excludes large hydropower and includes power plants running on other renewable energy sources.[15,16]

There were 205 grid-connected SHP plants in Sri Lanka at the end of 2019, with a total installed capacity of 424.6 MW and which generated a total of 1,011.0 GWh the same year.[8] SHP potential in the country has been estimated at 873 MW, indicating that approximately 49 per cent has been developed.[15,17] Relative to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed SHP capacity in Sri Lanka has increased by almost 19 per cent due to the construction of additional plants, while potential capacity has remained the same, as no comprehensive updated estimate of SHP potential has been produced (Figure 3).[15]

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



Source: SEA,[8] *WSHPDR 2019*,[15] *WSHPDR 2013*,[18] *WSHPDR 2016*[19]

The development of SHP in Sri Lanka has a long history, with the first SHP plant commissioned in 1996.[17] SHP development has been concentrated in the central parts of the country, with the Ratnapura and Nuwara Eliya districts leading the country in installed SHP capacity. Sri Lanka has developed considerable expertise in SHP, which it has sought to market internationally, with SHP developers from Sri Lanka involved in SHP projects in other parts of Asia as well as in African countries.[20] Domestic development of SHP in Sri Lanka is actively ongoing, with 11 new SHP plants commissioned in 2019.[8] However, bottlenecks in the procurement process have led to delays in the construction of a large number of projects with a cumulative capacity of 100 MW and no new standardized power purchase agreements (SPPAs) for SHP have been approved by the Government since 2015.[17,21] A list of recently commissioned SHP plants is available in Table 1.

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

Name	*Capacity (MW)*	*Operator*	*Launch year*
Koswathu Ganga	3.00	Finconsult Hydro Power Ltd	2019
Elgin	2.40	Elgin Hydropower Ltd	2019
Upper Hulu Ganga	1.90	Upper Hulu Ganga Ltd	2019
Marukanda	1.80	Kuruganga Hydro Ltd	2019
Loggal Oya	1.35	Loggal Oya Hydro Power Ltd	2019
Loinorn	1.00	Loinorn Hydro Ltd	2019
Denipalle Oya	0.75	Energy Craft Ltd	2019
Deegalahinna Cascade II	0.55	Deegalahinna Mini Hydro Power Ltd	2019
Moragahakanda Phase I	10.00	Ministry of Mahaweli & Development & Environment	2018
Moragahakanda Phase II	7.50	Ministry of Mahaweli & Development & Environment	2018
Moragahakanda Phase III	7.50	Ministry of Mahaweli & Development & Environment	2018
Bambarapana	2.50	Bambarapana Hydropower Ltd	2018
Manakola	2.50	H Hydro WV Ltd	2018
Udawela	1.40	Udawela Hydro Ltd	2018

Name	Capacity (MW)	Operator	Launch year
Ankanda	1.20	Escas Ankanda Ltd	2018
Polgaswaththa	1.00	S&N Power Mini Hydro Power Project Ltd	2018
Thannewatha	1.00	Thannewatha Mini Hydro Power Holding Ltd	2018
Maliyadda	0.90	Biomed Hydro Power Ltd	2018
Mossville Estate	0.90	Mossville Hydro Power Ltd	2018
Ranwala Oya	0.70	J B Power Company Ltd	2018

Source: SEA[8,22]

RENEWABLE ENERGY POLICY

The key element driving the renewable energy policy of Sri Lanka is the cost of fossil fuel imports for power generation in the country, which exceeded USD 100 million per month in 2022.[23] Policy decisions on renewable energy are guided by the Sri Lanka Sustainable Energy Authority (SEA), established by the Sustainable Energy Authority Act No. 35 of 2007.[24] The SEA acts as the regulator of renewable resource use and land allocation for renewable energy projects.[15]

As part of its Energy Sector Development Plan for a Knowledge-Based Economy 2015–2025, the Government of Sri Lanka had set a target of a 100 per cent share of electricity generation from renewable energy sources by 2030.[25] However, this target has been subsequently revised to 70 per cent, while aiming to achieve carbon neutrality by 2050.[26]

These targets are to be fulfilled in part through the expansion of solar power capacity to a total of 2,000 MW by the end of 2023.[26] The Renewable Energy Resource Development Plan 2021–2026 outlines the focus of future renewable energy development on prioritizing large- and medium-scale renewable energy parks with cumulative capacities in the range of 100 MW, without neglecting the development of smaller-scale capacities. For hydropower, the Plan identifies an undeveloped potential capacity of 1,082 MW for run-of-river hydropower plants, without specifying an upper installed capacity threshold.[27]

In 2010, Sri Lanka launched a programme of incentivizing renewable energy development through feed-in tariffs (FITs), at the time some of the highest in the Global South.[28] The country subsequently transitioned to a bidding system for renewable energy tenders, which lowered power purchase prices for electricity from renewable energy sources to an average of 18 LKR/kWh (0.050 USD/kWh), from the 22–25 LKR/kWh (0.061–0.069 USD/kWh) under the FIT system.[29] However, in June 2022 the Government acted to remove the competitive bidding system for renewable energy projects, justifying the change by a need for rapid addition of new renewable energy capacity to the grid.[30]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Barrier to SHP development in Sri Lanka include the following:

- Legal and administrative bottlenecks preventing the signing of new SPPAs with SHP developers;
- Lack of an up-to-date estimate of the remaining undeveloped SHP potential;
- Issues at the grid and subgrid level interfering with power connections to, and transmission of, power from new SHP plants;
- Lack of community involvement in SHP development and unequal sharing of value generated by SHP plants among local communities;
- Absence of effective monitoring of SHP plant development and operation to ensure environmental compliance;
- Public opposition to further SHP development.[15]

Enablers to SHP development in Sri Lanka include:

- Considerable local technical expertise in domestic and international SHP development;
- Abundant remaining potential SHP capacity in some parts of the country;
- Demand for renewable energy development due to the high cost of fossil fuel imports;
- Government policy strongly supportive of renewable energy development.

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Contributing organizations

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