UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

INTERNATIONAL CENTER
ON SMALL HYDROPOWER

World Small Hydropower Development Report 2022

Western Asia

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Suggested citation:

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

ISSN: 2406-4580 (print)
ISSN: 2706-7599 (online)

The digital copy is available at www.unido.org/WSHPDR2022.

Design: red not 'n' cool
Cover Picture: depostihphotos

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Acknowledgements

The World Small Hydropower Development Report 2022. was prepared under the overall guidance of Tareq Emtairah, Director of the Division of Decarbonization and Sustainable Energy, Petra Schwager-Kederst, Chief of the Division of Climate and Technology Partnerships at the United Nations Industrial Development Organization (UNIDO) and LIU Deyou, Director General of the International Center on Small Hydropower (ICSHP).

The preparation of this thematic publication was headed by LIU Heng, Senior Technical Advisor at UNIDO and consulted by HU Xiaobo, Chief of the Division of the Multilateral Development at ICSHP. The work was coordinated by Oxana Lopatina at ICSHP and Eva Krēmere at UNIDO. The publication is the result of three years of intense research work and was backed by a talented and indispensable team of researchers at ICSHP and a vast number of experts in the field of small hydropower

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Western Asia

Countries: Armenia, Azerbaijan, Georgia, Iraq, Israel, Jordan, Lebanon, Saudi Arabia, Syria, Turkey

INTRODUCTION TO THE REGION

The electricity sectors of Western Asia reflect the different resources available to countries in the region. Saudi Arabia and Iraq are major international oil exporters and their energy mixes are dominated by fossil fuels. By contrast, Turkey has a highly diversified energy mix, while Jordan has made considerable investment in solar power as well as wind power to offset its dependence on fossil fuel imports. Ongoing conflict has caused considerable disruptions to the power grids of Iraq and Syria, and Lebanon has been struggling with a multi-faceted economic crisis that has caused a near-collapse of grid-connected generating capacity due to lack of fuel. The electricity sectors of most countries in the region are dominated by state-run companies, although private electricity companies play a significant role in Israel, Armenia and particularly in Turkey.

Turkey leads the region in hydropower development, owing to its abundant water resources. Hydropower is the single most significant energy source in terms of installed capacity in Turkey as well as in Georgia and Armenia, although actual electricity generation from hydropower in Turkey and Armenia lags behind that of other energy sources. In Iraq, Syria, Lebanon and Azerbaijan, hydropower plays a supplementary role, and it forms only a minor part of the electricity mix of Jordan. Due to the presence of transboundary rivers and overall water scarcity in Western Asia, disputes over hydropower resources have contributed to geopolitical tensions and conflict in parts of the region.

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

Table 1. **Overview of Western 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)*
Armenia	3	100	100	2,879	7,723	1,346	1,778
Azerbaijan	10	100	100	7,622	25,839	1,149	1,070
Georgia	4	100	100	4,533	11,857	3,323	8,932
Iraq	40	100	100	27,661	87,900	1,864	5,000
Israel	9	100	100	17,972	110,600	N/A	N/A
Jordan	11	N/A	N/A	5,728	20,996	12	18
Lebanon	7	100	100	3,083	14,501	282	424
Saudi Arabia	35	100	100	85,200	340,900	N/A	N/A
Syria	26	89	76	9,803	26,586	1,505	1,614
Turkey	84	100	100	95,890	305,500	30,984	78,116
Total	-	-	-	**260,370**	-	**40,465**	-

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 Western Asia is not uniform. Many countries in the region, including Azerbaijan, Jordan, Lebanon, Syria and Turkey, have adopted the up to 10 MW definition, while Georgia adheres to the up to 15 MW definition and Armenia to the up to 30 MW definition. No official SHP definition exists in Iraq, Israel, or Saudi Arabia.

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

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

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed capacity (≤10 MW)*	*Potential capacity (≤10 MW)*
Armenia	Up to 30 MW	382.0	430.6	340.0	340.0
Azerbaijan	Up to 10 MW	49.5	520.0	49.5	520.0
Georgia	Up to 15 MW	263.0	723.9	212.2	491.8
Iraq	N/A	N/A	N/A	6.0	62.4
Israel	N/A	N/A	N/A	7.0	7.0*
Jordan	Up to 10 MW	12.0	N/A	12.0	12.0*
Lebanon	Up to 10 MW	31.2	144.8	31.2	144.8
Saudi Arabia	N/A	N/A	N/A	0.0	130.0
Syria	Up to 10 MW	23.0	67.6	23.0	67.6
Turkey	Up to 10 MW	1,662.2	4,891.5	1,662.2	4,891.5
Total	-	-	-	**2,343.1**	**6,667.1**

Source: *WSHPDR 2022*[1]

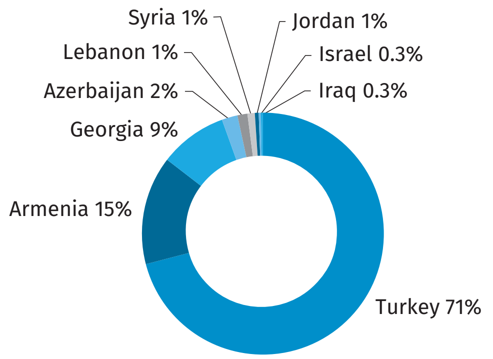
Note: *Based on installed capacity as data on total potential capacity are not available.

The most significant SHP capacities in Western Asia exist in Turkey as well as the countries of the Southern Caucasus, particularly Armenia and Georgia. In other parts of the region, SHP forms only a small part of the total installed hydropower capacity, as regional climatic and topographical conditions make the construction of SHP plants on smaller streams impractical due to their seasonal variability.

The total installed capacity of SHP up to 10 MW in Western Asia is 2,343.1 MW, while the potential capacity is estimated at 6,667.1 MW. The installed capacity of SHP has decreased by nearly 34 per cent relative to the *World Small Hydropower Development Report (WSHPDR) 2019,* while potential capacity has decreased by nearly 16 per cent. The primary reason for this decrease were updates to SHP databases and cancellations of ongoing and prospective SHP projects in Turkey due to economic and environmental factors. At the same time, SHP development in Turkey is ongoing, with several new projects commissioned in 2020, and active development of SHP is taking place in Armenia, Georgia and Azerbaijan. Elsewhere in Western Asia, little activity in the SHP sector has been observed. Countries in the region with limited new stream SHP potential are exploring options for SHP development on existing water supply infrastructure.

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

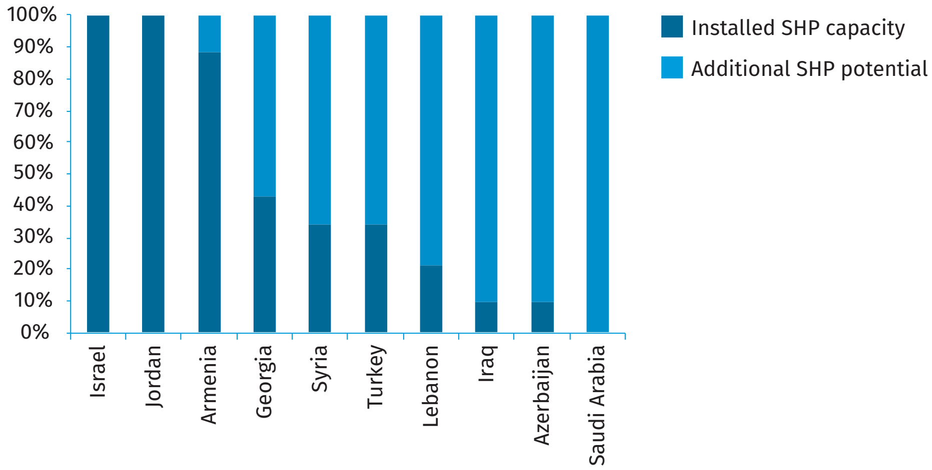
Figure 1. **Share of Regional Installed Capacity of Small Hydropower by Country in Western Asia (%)**



Source: *WSHPDR 2022*[1]

Note: For SHP up to 10 MW.

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



Source: *WSHPDR 2022*[1]

Note: For SHP up to 10 MW in the case of Israel, Georgia, Syria, Turkey, Lebanon, Jordan, Iraq, Azerbaijan and Saudi Arabia; for SHP up to 30 MW in the case of Armenia.

In **Armenia**, there were 188 SHP plants up to 30 MW as of 2021 with a total installed capacity of 382 MW, of which 186 plants were up to 10 MW with a total installed capacity of approximately 340 MW. The potential capacity for SHP up to 30 MW is estimated at 430.6 MW, indicating that approximately 89 per cent has been developed. Ongoing SHP development has included the commissioning of 11 new SHP plants in the last several years, and 24 SHP projects with a total capacity of nearly 49 MW were under construction as of early 2021.

The installed capacity of SHP up to 10 MW in **Azerbaijan** was estimated at 49.5 MW as of 2022 while potential capacity is approximately 520 MW, indicating that nearly 10 per cent has been developed. Several new SHP plants were constructed in the country between 2017 and 2020 and several additional plants formerly operated by the de-facto authorities in Nagorno-Karabakh were refurbished and recommissioned in 2021. In addition, a further 23 non-operational SHP plants are slated for refurbishment in the near future.

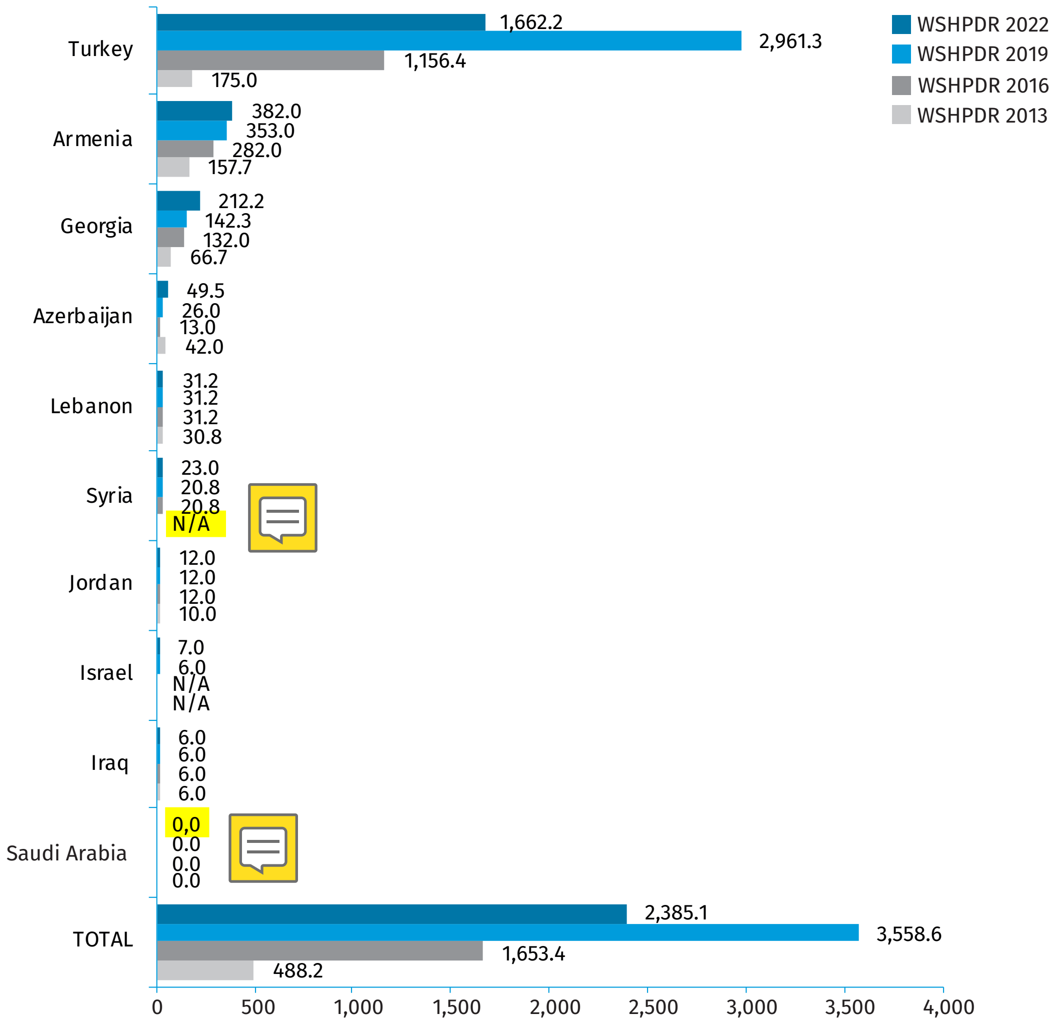
In **Georgia**, the total installed capacity for SHP up to 15 MW was approximately 263 MW as of 2021 and approximately 212 MW for SHP up to 10 MW. The official definition of SHP in the country was altered from up to 13 MW to up to 15 MW in 2019. Under the new definition, there were 72 SHP plants in operation as of 2021, of which 68 were plants up to 10 MW. Potential capacity for SHP up to 15 MW is estimated at 724 MW, indicating that 36 per cent has been developed, and for SHP up to 10 MW at nearly 492 MW, indicating that 43 per cent has been developed. A very large number of SHP plants have been constructed in the country between 2017 and 2020, with capacities ranging from 0.5 MW to 9.5 MW. As of December 2020, there were a total of 74 SHP projects under construction, applying for licences or undergoing feasibility studies.

The installed capacity of SHP in **Iraq** is 6 MW, provided by a single SHP plant. Potential capacity for SHP up to 10 MW is estimated to be at least 62 MW, suggesting that less than 10 per cent has been developed. Currently, there are no plans for SHP development as the country has prioritized solar power and wind power projects.

The total installed SHP capacity in **Israel** is estimated at 7 MW and has not changed over the last decade. Data on specific plants as well as on the total SHP potential in the country are not available. Studies on opportunities for SHP development in Israel as well as experimental projects on SHP installation on water supply infrastructure have been carried out over the last decade, but no specific plans for SHP development in the country have been proposed or implemented.

There are two operational SHP plants in **Jordan**, both constructed in the 1980s, with a total installed capacity of 12 MW, but only one plant is actively producing electricity. There is no reliable data on SHP potential in the country. As of 2021, there were no ongoing SHP projects or official plans for SHP development in the country.

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



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

Note: For SHP up to 10 MW in the case of Turkey, Georgia, Azerbaijan, Lebanon, Syria, Jordan, Israel, Iraq and Saudi Arabia; for SHP up to 30 MW in the case of Armenia.

The installed capacity of SHP up to 10 MW in **Lebanon** is 31.2 MW and has not changed in several decades, with the country's still-operational SHP plants constructed during the pre-civil war period. Potential for SHP up to 10 MW has been assessed by several detailed studies and is estimated at 144.8 MW, indicating that 22 per cent has been developed, but there are no plans for further SHP development in the country.

Saudi Arabia has no SHP sector and no plans for the development of SHP. However, untapped SHP potential is estimated to total approximately 130 MW. This potential is mainly accounted for by non-powered dams, including 6 dams with a potential capacity of between 45 MW and 51 MW and 51 smaller dams with a potential capacity of 82 MW.

Syria has three operational SHP plants up to 10 MW with a total installed capacity of approximately 23 MW. The total potential for SHP up to 10 MW in the country is estimated at 67.6 MW, suggesting that 34 per cent has been developed. No significant SHP development has taken place in the country since the 1960s. The Government of Syria has been exploring options for re-energizing the SHP sector as a means to offset the loss of electricity capacity caused by the ongoing conflict and sanctions. A government study commissioned in 2020 conducted a detailed investigation of the potential for SHP development in current conditions, with a particular focus on developing hidden SHP potential found in existing water supply infrastructure, outflow from industrial sites and non-powered dams.

The total installed capacity of SHP up to 10 MW in **Turkey** was 1,662.2 MW as of 2020. The potential capacity was estimated at 4,891.5 MW, indicating that 34 per cent has been developed. Both installed and potential capacity of SHP in the country have decreased considerably relative to the *WSHPDR 2019* following updates to databases of SHP plants and the cancellation of over 600 SHP projects. The causes of these cancellations included technical issues, environmental factors including drought and difficulty in obtaining licences. The private sector plays an important role in SHP development in the country, with 714 SHP plants put into operation under public-private partnerships.

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

Climate Change and Small Hydropower

Several countries in the Western Asia region have limited water resources, and climate models indicate an increase in evaporation and a reduction in rainfall. The long-term effects are expected to have an impact on hydropower generation. For example, Lebanon is expecting a decline in annual hydropower generation of 540 GWh by 2090. In the Caucasus region, impacts vary across river basins. In Armenia, annual river flow is projected to decline by 39 per cent by 2100, significantly impacting SHP as most plants are built on natural watercourses.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Armenia has a wide range of policies that have contributed to active SHP development in the country, including feed-in tariffs (FITs) for SHP differentiating between several categories of projects. At the same time, the regulatory framework for SHP in Armenia has become increasingly strict due to environmental concerns and legislation promoting the use of renewable energy currently favours energy sources other than SHP, in particular solar power. Most importantly, remaining undeveloped SHP potential in the country is nearly exhausted and is likely to be filled by ongoing projects following their completion. Subsequently, opportunities will remain in the area of refurbishment of ageing SHP plants, of which there is a considerable number.

Azerbaijan has considerable undeveloped SHP potential as well as a number of SHP plants in need of immediate refurbishment. The country has recently adopted a new Law on the Use of Renewable Energy Sources in the Production of Electricity that provides for guaranteed purchase tariffs and grid connections for renewable energy projects, in addition to tax exemptions and subsidies provided by previous legislation. However, up-to-date studies on SHP potential in the country are lacking and heavy reliance on electricity generation from cheap domestic fossil fuels presents an obstacle to renewable energy development as a whole.

In **Georgia** there are several factors favouring SHP development, including the structure of the electricity market, which favours independent power producers, as well as commitments on reductions of greenhouse gas emissions by many municipal governments under the Covenant of Mayors framework, which have driven renewable energy development in the country. At the same time, there is a lack of government support for SHP in the form of tax incentives or FITs and only limited local manufacturing capacity. An additional obstacle is the lack of up-to-date information on SHP potential, particularly in view of shifting hydrological conditions due to climate change.

SHP potential in **Iraq** is represented by several undeveloped sites with potential capacities ranging between 5 MW and 10 MW, as well as a large number of non-powered dams and barrages with a total potential capacity of over 26 MW. However, the reliance of Iraq on cheap domestic fossil fuels as well as on large hydropower for electricity generation represents a major obstacle to SHP development, and the country's renewable energy policy is focused on solar and wind power.

There is no clear data on SHP potential in **Israel** and the country's renewable energy policy has prioritized solar power and wind power plants. As elsewhere in the region, one of the main realistic options for SHP development in the country is the installation of micro-hydropower turbines on existing water supply networks.

Opportunities for SHP development in **Jordan** include the installation of SHP on several non-powered dams as well as a number of potential sites for dedicated SHP plant construction identified in a 2012 study. While Jordan is actively pursuing renewable energy development, the country's focus on solar power and wind power is likely to continue into the foreseeable future.

Despite substantial undeveloped SHP potential in the country, further large-scale SHP development in **Lebanon** is unlikely due to the lack of economic capacity for carrying out SHP projects, increasing water stress, low electricity purchase prices by the grid operator and the leading role of other renewable energy sources in driving the energy transition of the country, particularly solar power. Existing SHP plants in the country are in need of refurbishment, which may represent an opportunity for future projects in the sector.

The prospects for SHP development in **Saudi Arabia** are limited due to the lack of permanent rivers and heavy reliance on cheap domestic fossil fuel resources. The main potential for SHP development in the country lies in the installation of SHP plants on non-powered dams, outflow from industrial sites and energy recovery solutions on existing water supply infrastructure, including desalination plants.

Owing to climatic and economic limitations, there are few opportunities for SHP development in **Syria**. The primary options for further activity in the sector include the refurbishment of existing plants and installation of SHP plants on non-powered dams, outflow from water treatment facilities as well as on water supply infrastructure, particularly break pressure tanks.

Turkey has a large SHP sector and prospects for further development of SHP are strong due to a robust technical capacity and a well-established framework of incentives for SHP, including several types of FITs and tax exemptions. At the same time, bureaucratic hurdles and environmental factors including variability of river flows have led to the closure of a large number of projects in recent years. Additionally, certain existing legislation promoting SHP does not set an upper capacity threshold, encouraging developers to pursue larger and more cost-effective projects.

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Armenia

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KEY FACTS

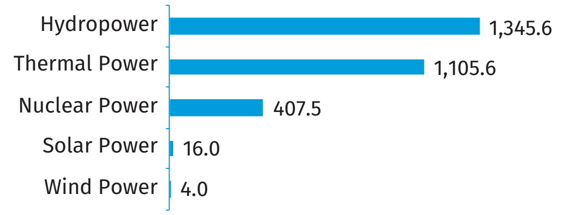
Population	2,963,300 (2020)[1]
Area	29,743 km^2 [1]
Topography	Armenia is a mountainous country with the lowest point near the Debed River in the north, at 375 metres above sea level, and the highest point on the northern peak of Mount Aragats at 4,095 metres. The average altitude is 1,830 metres above sea level, with 90 per cent of the area lying above 1,000 metres, of which 40 per cent is above 2000 metres. Such significant variations in altitude have important effects on the climatic and landscape zones within the country.[2,3]
Climate	Armenia is a country of great climatic diversity. Almost all climatic variations can be observed in the country, including dry subtropical and cold mountainous zones. The average annual air temperature ranges from -8 °C in mountainous areas to 12–14 °C in valley regions. Summer is mild, with an average temperature of 16.7 °C in July and as high as 24–26 °C in the Ararat Valley. Winter is quite cold, with January, the coldest month, averaging a temperature of -6.7 °C. The climate of Armenia is also characterized by intense and abundant solar radiation, with an average annual irradiance of approximately 1,700 kWh/m^2 and 2,500 sunshine hours per year. The average annual wind velocity varies greatly across Armenia: from 1 m/s in Meghri to 8 m/s in Sisian. In the summer, the velocity of the mountain winds can reach 20 m/s or more. The territory of Armenia is characterized by a high frequency and magnitude of hazardous hydrometeorological phenomena, leading to emergency situations.[3]
Climate Change	Significant increase in the annual temperature in Armenia has been observed in the last few decades. Relative to the 1961–1990 annual average of 5.5 °C, the annual average temperature increased by 0.4 °C during the period of 1929–1996 and during the period of 1929–2016 by 1.23 °C. Precipitation during the period of 1935–2016 decreased by almost 9 per cent compared to the annual average (592 mm) for the period 1961–1990.[3]
Rain Pattern	The climate in Armenia is relatively dry, with an average annual precipitation of 592 mm. High mountainous regions receive the greatest amount of precipitation, in the range of 800–1,000 mm annually. The driest regions are the Ararat Valley and Meghri regions, with an average annual precipitation of 200–250 mm. Average precipitation in the Ararat Valley during the summer does not exceed 32–36 mm.[3]
Hydrology	There are approximately 9,500 small and medium rivers flowing through the territory of Armenia, with a total length of approximately 25,000 km. The longest rivers the Akhurian (186 km), Araks (158 km), Debed (154 km), Hrazdan (141 km) and Vorotan (119 km). The density of the river network ranges from 0 to 2.5 km/km^2 in different parts of the country. Rivers in Armenia have a highly uneven flow distribution across years and seasons, with an average surface flow of 6.8 billion m^3. The largest lake in the country is Lake Sevan, located at 1,900.5 metres above sea level, with a surface area of 1,287.7 km^2 and a volume of 38.2 km^3. Besides Lake Sevan, there are approximately 100 small mountain lakes with a total volume of 0.8 km^3. Additionally, 87 reservoirs with a total volume of 1.4 billion m^3 have been constructed in Armenia to address the seasonal fluctuations in the river flow. Groundwater reserves in Armenia account for approximately 4.0 billion m^3. They play an important role in the country's overall water balance, with approximately 96 per cent of the drinking water and more than 40 per cent of the total water intake coming from groundwater. The largest water consumer in Armenia is the irrigation sector.[3]

ELECTRICITY SECTOR OVERVIEW

Armenia possesses rather scarce fossil fuel resources, having no oil reserves, no oil production and no refineries. There are no oil pipelines, and refined products arrive through rail or truck shipments. Thermal power plants are fuelled mainly by natural gas. Domestic primary energy sources, including hydropower, nuclear power, wind power and biomass, contribute approximately 27 per cent of the total primary energy supply, which equalled 3,595.5 ktoe in 2020.[4]

In 2020, total electricity generation was 7,723.4 GWh. Approximately 41 per cent (3,165.6 GWh) was provided by thermal power, 36 per cent (2,756.3 GWh) was provided by nuclear power and 23 per cent (1,778.4 GWh) was provided by hydropower. The contribution of wind and solar power was negligible at approximately 0.3 per cent (23.2 GWh) (Figure 1).[5]

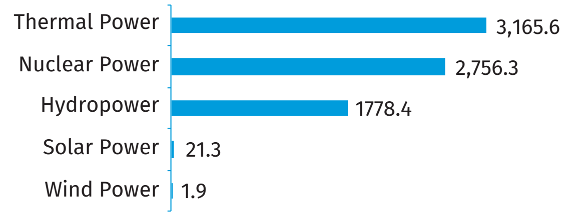
Figure 1. **Annual Electricity Generation by Source in Armenia in 2020 (GWh)**



Source: PSRC[5]

The total installed capacity in Armenia in 2020 was 2,878.7 MW. Approximately 47 per cent of total installed capacity (1,345.6 MW) was from hydropower, 38 per cent (1,105.6 MW) was from thermal power and 14 per cent (407.5 MW) was from nuclear power. Wind and solar power together accounted for less than 1 per cent (20 MW) of the installed capacity (Figure 2).[6] There is also a further 1,284 MW of thermal power capacity from plants and units that are presently out of operation or partly dismantled, and are therefore not included in the total installed capacity.

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



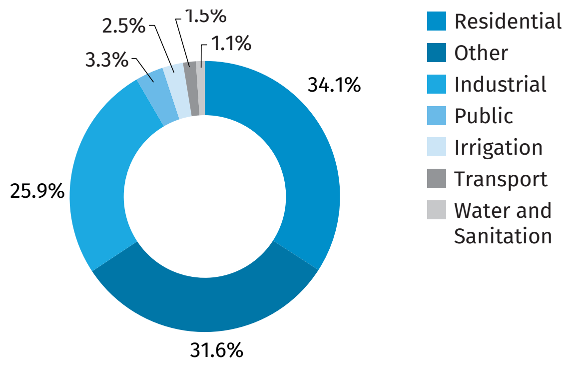
Source: Government of the Republic of Armenia[6]

The one nuclear power plant operating in Armenia (ANPP) meets between 30 and 50 per cent of the country's electricity needs depending on plant uptime. There is international pressure on Armenia to decommission this plant due to perceived seismic risk. However, the Government is reluctant to do so until alternative generating capacity is online and the plant is scheduled to operate until 2026. Hydropower plants are represented by two cascades (Sevan-Hrazdan and Vorotan) and a number of small hydropower (SHP) plants. Hydropower meets between 20 and 40 per cent of the country's electricity needs depending on the amount of rainfall, which exhibits significant annual variation. There are also three condensed-type gas-fired thermal (CCGT) plants in operation, which cover the remaining electricity demand and are responsible for ensuring electricity exports to neighbouring countries. It is worth noting that Armenia is not only fully supplied with electricity over its entire territory, but is in fact equipped with excess installed capacities, due to a 2.5 decrease in electricity consumption since the end of the Soviet period.

The past few years have been marked by wide implementation of different solar installations such as rooftop solar photovoltaic (PV) installations, grid-connected solar power plants, solar water heaters, etc. There has also been some development of SHP capacities. The share of electricity generated from renewable sources in 2020 exceeded 23 per cent, provided almost entirely by hydropower.[5] Generation by solar and wind power has lagged behind the installed capacity of these energy sources, due to the low efficiency of many of the installed solar PV panels in Armenia and the temporary non-operational status of a number of installed wind turbines.

Armenia has interconnections with all neighbouring countries, but high voltage lines are under operation only with Georgia and Iran. In 2020, total electricity imports amounted to 320.3 GWh and exports to 1,333.1 GWh. Electricity consumption reached 5,810.4 GWh, with the residential sector accounting for 34 per cent of total consumption, the industrial sector for 26 per cent and the public sector, transport, irrigation, water supply and sanitation and other uses for the remaining 40 per cent (Figure 3).[5] The electrification rate in the country is 100 per cent.[7] Customers have full access to the electricity network and grid connection is available to any new user.

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



Source: PSRC[5]

The High Voltage Electric Networks (HVEN) Closed Joint-Stock Company (CJSC) is responsible for transmitting the power produced by generating companies to the distribution company, as well as for transporting both electricity imports and exports from and to neighbouring countries.[8] Another private company, the Electric Networks of Armenia CJSC (ENA), is responsible for distribution and is the sole buyer of power from all generating companies, as well as the sole seller of power to all customers at tariffs set by the Public Services Regulatory Commission of the Republic of Armenia (PSRC).[9] The ENA's distribution grid includes all lines and substations within the 0.4–110 kV range and all SHP plants in the country are connected exclusively to the distribution grid.

The PSRC is an independent regulatory authority, whose functions include drafting of the tariff methodology and approval of tariffs, issuing of licences and permits, development and control of service quality standards, review of customers' complaints and approval of investment plans.[10] The Government of Armenia does not provide subsidies to either consumers or producers of energy and all costs related to electricity pricing fall on the ENA. The ENA is obligated to purchase power from producers at the tariffs set by the PSRC and guarantees purchase of power from all licensed producers. The PSRC and ENA coordinate to ensure an adequate level of profit for the ENA, including adjusting tariffs to compensate for periods where ENA has incurred losses due to insufficient demand.

The tariffs for all final consumers set by the PSRC depend on the level of the feeding voltage and on the hours of usage. The consumer tariffs in effect as of 29 December 2020 are presented in Table 1.

Table 1. **Electricity Tariffs for Consumers in Armenia as of 29 December 2020**

	Price incl. VAT (AMD (USD) per kWh)	
Consumer type	*Day time*	*Night time*
110 kV and above voltage consumers	36.48 (0.075)	32.48 (0.070)
35 kV voltage consumers	38.98 (0.080)	34.98 (0.072)
6 (10) kV voltage consumers	44.98 (0.092)	34.98 (0.072)
0.38 kV voltage consumers (non-residential)	47.98 (0.098)	37.98 (0.077)
0.38 kV voltage residential consumers consuming more than 400 kWh/month	47.98 (0.098)	37.98 (0.077)
0.38 kV voltage residential consumers consuming up to 400 kWh/month (inclusive)	44.98 (0.092)	34.98 (0.072)
Residential low-income consumers	29.99 (0.061)	19.99 (0.041)

Source: PSRC[11]

Note: Night time tariffs are from 22:00 PM to 06:00 AM starting from the last Sunday of March until the last Sunday of October; and from 23:00 PM to 07:00 AM starting from the last Sunday of October until the last Sunday of March.

The Electro Power Systems Operator CJSC, otherwise known as the National Dispatch Centre, is responsible for the maintenance of technically admissible steady-state operations of the electricity network. It also manages the network in power emergencies and its restoration to acceptable operating conditions following such emergencies.[12] The Settlement Centre CJSC collects and processes data on power flows in the electricity network and on technical parameters of the regime by means of an automated data acquisition and metering system, as well as provides the processed data to other market participants.[13]

To promote the gradual liberalization of the electricity market and interstate trade, on 7 February 2018 the National Assembly of the Republic of Armenia adopted amendments and addenda to the laws "On Energy", "On Licensing" and "On State Duty", taking into account recommendations made by international organizations.[14,15,16] These decisions marked the beginning of the process of liberalization of the Armenian electricity market. The "Program-Timeline of Measures towards Liberalization and Interstate Trade Development of the Electricity System of the Republic of Armenia" was adopted by Government Decree No. 1010-L from 14 September 2018.[17]

The liberalization of the Armenian electricity market means that the market will move from a "one buyer" model to a free electricity purchase and sale mechanism. "Temporary commercial rules of the wholesale electricity market of the Republic of Armenia" were approved by Resolution of the Public Services Regulatory Commission (PSRC) No. 344 from 9 August 2017, which defined the participants of the wholesale electricity market and its structure and regulates commercial relations among participants.[18,19,20]

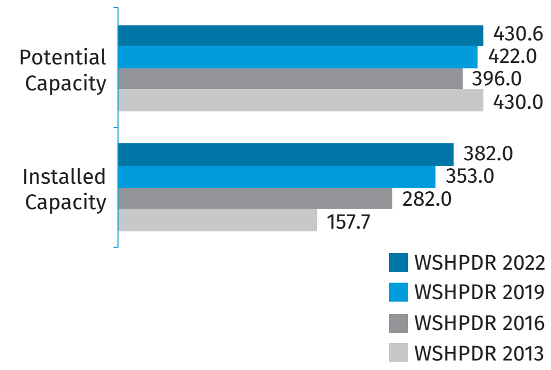
New trade rules for the electricity wholesale and retail markets in the Republic of Armenia, as well as network rules for transmission and distribution, sample forms of relevant contracts and indicators for safety and reliability were outlined by PSRC Resolutions No. 516-N and No. 523-N from 25 December 2019. These amendments, which are to be applied from 1 February 2021, should ensure the introduction of the new electricity market model.[21,22] The "Republic of Armenia Energy Sector Development Strategic Programme to 2040", approved by Government Decision 48-L from 14 January 2021 and superseding previous strategic energy documents, outlines the planned vectors of development of the energy sector. Major elements of the Programme include the wide implementation of solar PV and the full utilization of all remaining economically viable hydropower potential, in particular SHP. It is expected that all new power plants will be constructed on a public-private partnership (PPP) basis or entirely through private investments.[23]

SMALL HYDROPOWER SECTOR OVERVIEW

On the basis of Government Decision No. 1300-A from 8 September 2011, SHP plants are defined as those with installed capacity less than 30 MW.[24]

As of 1 January 2021, 188 SHP plants up to 30 MW with a total installed capacity of 382 MW and average annual generation of approximately 951.7.6 GWh were in operation in Armenia. Of these, 186 plants were SHP plants up to 10 MW with a total installed capacity of approximately 340 MW.[25] The list of 20 most recently commissioned SHP plants is presented in the Table 2. The potential capacity of SHP up to 30 MW, based on the number of existing plants and licensed projects, is 430.6 MW.[25] Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, installed capacity increased by approximately 8 per cent, and potential capacity by approximately 2 per cent (Figure 4).[26] The increase is primarily accounted for by the construction of 11 new SHP plants and the granting of several additional licenses for future projects, respectively.

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



Source: PSRC,[25] *WSHPDR 2019*,[26] WSHPDR *2013*,[27] *WSHPDR 2016*[28]

Note: Data for or SHP up to 30 MW.

Table 2. **List of Selected Operational Small Hydropower Plants in Armenia**

Name	*Location*	*Capacity (MW)*	*Head*	*Plant Type*	*Operator*	*Launch year*
Astghaberd	Syunik	7.795	165	Run-of-river	TELIA MINING LLC	2020
Kaputjugh	Syunik	1.227	120	Run-of-river	AREV EV JUR LLC	2020
Aygdzor	Tavush	0.440	105	Irrigation system, run-of-river	Atlas-Energo LLC	2019
Aparan	Aragatsotn	1.512	27	Irrigation system, run-of-river	NIGAVA LLC	2019
Garni	Kotayk	1.333	184	Run-of-river	Narenergo LLC	2019
Gornar	Vayots Dzor	3.908	542	Irrigation system, run-of-river	GREEN ENERGY AMERICAN CONCERN LLC	2018
Her-Her	Syunik	1.200	34	Irrigation system, run-of-river	Her-Her HPP CJSC	2018
Sahakyan SHPP-2	Lori	2.434	103	Run-of-river	Energostil CJSC	2018
Qajarants	Syunik	3.081	203	Run-of-river	SUN AND WATER LLC	2018
Chqnacgh	Syunik	3.310	221	Run-of-river	GREEN POWER LLC	2018
Jermuk-1	Vayots Dzor	2.547	65	Run-of-river	Jermuk Turboshin LLC	2018
Meghri-1	Syunik	2.400	88	Run-of-river	GREEN POWER LLC	2017
Arpa-2	Syunik	2.775	316	Run-of-river	GINJ ARPA LLC	2017
Arpa-3	Syunik	3.600	131	Run-of-river	GINJ ARPA LLC	2017
Kok	Tavush	0.973	18	Run-of-river	KOK SYSTEM LLC	2017
Vorotan-7	Syunik	3.610	106	Run-of-river	VOROTAN SYSTEMS LLC	2017
Gndevank	Vayots Dzor	1.500	165	Run-of-river	FERA LLC	2017
Amberd SHPP-3	Aragatsotn	9.830	293	Run-of-river	Amberd HPP LLC	2017
Seka	Syunik	1.040	122	Run-of-river	KARALEVAS LLC	2016
Anapat-1	Syunik	3.887	293	Run-of-river	TATEV ANAPAT LLC	2016

Source: PSRC[25]

As of 1 January 2021, 24 ongoing SHP projects with a total installed capacity of 48.6 MW and an expected annual electricity production of approximately 173 GWh had licences and were under construction.[25] Data on the five most recent SHP projects are displayed in Table 3.

Table 3. **List of Selected Ongoing Small Hydropower Projects in Armenia**

Name	*Location*	*Capacity (MW)*	*Head*	*Plant Type*	*Developer*	*Planned Launch Year*	*Development Stage*
Tashir	Lori	0.990	32	natural water flow	Stepdzor LLC	2021	Under construction
Eri Dzor	Tavush	0.990	222	Irrigation system	Atlas-plus LLC	2021	Under construction
Akhuryan SHPP-2	Shirak	2.418	39	natural water flow	Musaha LLC	2022	Under construction
Chanakhchi HPP-2	Lori	0.260	102	natural water flow	Mavr LLC	2022	Under construction
Jimel	Syunik	0.400	234	Irrigation system	JIMEL LLC	2023	Under construction

Source: PSRC[25]

Note: As of January 2021.

The theoretical generation potential of hydropower in Armenia is estimated at 21,800 GWh/year, including 18,600 GWh/year for large and medium rivers and 3,200 GWh/year for small rivers. Technically available potential is estimated at approximately 7,000–8,000 GWh/year and economically feasible potential at 3,200–3,500 GWh/year.[29]

RENEWABLE ENERGY POLICY

The Republic of Armenia Energy Sector Development Strategic Programme to 2040 sets the maximum use of renewable energy potential as the primary development priority. Among other targets, the programme envisages wide implementation of solar PV (approximately 1,000 MW), as well as sets targets to construct approximately 50 MW of SHP capacity by 2023.[23] The Armenian Energy system least-cost development study, which was the basis for the preparation of the Strategic Programme, shows that greenhouse gas (GHG) emission reduction targets under Armenian Nationally Determined Contribution (NDC) could be achieved only through the full implementation of the mentioned renewable energy projects together with the extension of the service of the nuclear power capacities currently available in the country.[30]

Laws adopted in recent years to support and regulate renewable energy development include amendments and supplements to the Law on Energy aimed at the creation of conditions conducive to the advancement of renewable energy sources:

- A 20-year purchase guarantee provision is established for electricity produced by renewable energy sources other than SHP, for which the old 15-year purchase guarantee applies; it is assumed the investor will recoup the cost of development within this period;
- Activities which are not subject to regulation only include the production of electricity exclusively for self-consumption purposes, as well as the production of electricity by autonomous producers with an installed capacity of up to 150 kW during the period of production;
- The 150 kW capacity limit for autonomous solar power plants not subject to regulation during the construction and production periods has been replaced by a 500 kW capacity limit for the 2018–2022 period.[31,32,33,34,35,36]

Additional legislative changes have included amendments to the Law on Energy Saving and Renewable Energy, aimed at creating an enabling environment for the operation of solar power plants by establishing a procedure for interconnections between an autonomous power generator and an electricity distribution licence holder.[37,38,39] Meanwhile, the 2019 Law on Making Addendum and Amendments to the Water Code of the Republic of Armenia includes the following regulations, specifically relevant to SHP development:

- Defines specifies zones where construction and operation of SHP plants are prohibited;
- Establishes grounds for refusing applications for water use permits for newly constructed SHP plants. The Government hereby reserves the authority to define the list of rivers which provide habitats for the spawning of endemic fish species included in the IUCN Red List of Threatened Species.[40,41,42,43]

Renewable energy development in Armenia is promoted in part through the tariff policy set by the PSRC, which currently favours solar PV. The tariff policy is based on the principle of ensuring adequate revenue levels for producers and is aimed at sustaining normal economic activity in this sphere and balancing the interests of consumers and regulators, while also enabling the implementation of prospective development projects. A fixed tariff system is applied for plants using renewable energy sources. Within the framework of this system the tariffs are adjusted every year, taking into account inflation and fluctuations in the AMD/USD exchange rate. This targeted policy has already had significant success, as evidenced by the recent rapid development of solar PV plants in Armenia.

Feed-in tariffs (FITs) for electricity produced by SHP plants effective from 1 July 2021 until 1 July 2022, are as follows (exclusive of VAT of 20 per cent):

- For SHP plants built on natural water streams: 26.185 AMD/kWh (0.053 USD/kWh);
- For SHP plants built on irrigation systems: 17.454 AMD/kWh (0.035 USD/kWh);
- For SHP plants built on natural drinking sources: 11.637 AMD/kWh (0.023 USD/kWh).[44]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

Licensing of electricity generating companies is the sole right of the PSRC. There is a unified procedure to obtain a licence, which applies to all types of electricity producers, including SHP. The issuing of the licence by the PSRC after examination of the application package is contingent on adherence to standards and norms. The list of documents to be submitted with an application for an electricity licence includes the following items:

- Business plan;
- Certificate of ownership or lease of the applicant's land;
- Announcement on the official website of public notices of the Republic of Armenia;
- Guarantee from the bank on compensation in case of violation of the terms of the licence by the applicant;
- Water use permit for hydropower plants, as well as for other types of plants if required by law;
- A contract or permit establishing connection and construction access for the applicant to water infrastructure owned by other parties in the case of hydropower plants built on drinking water pipes or irrigation systems;
- Certificate of the possibility of connection to the electricity network;
- In case of a PPP transaction, a copy of the PPP agreement.[45]

It should be noted that the 50 MW SHP target set by the Energy Sector Development Strategic Programme to 2040 has significant implications for SHP prospects in the country. As of 2021, the target had been nearly achieved by already-licensed and ongoing projects, with a total planned capacity of 48.6 MW. Therefore, little room remains for additional SHP development, as no new SHP licences are likely to be issued for the foreseeable future.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Projected changes in river flow in Armenia vary across different river basins due to differences in the basins' natural and climatic characteristics, as well as in other factors contributing to flow formation. Annual river flows are projected to decline by up to 14 per cent by 2040, 28 per cent by 2070 and 39 per cent by 2100, relative to the baseline annual average for 1961–1990 (6,279.9 million m^3). A reduction in river flow can be expected to affect SHP generation in Armenia, as most SHP plants in the country are built on natural watercourses.[3]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

A number of legislative improvements introduced in recent years, as well as the strengthening of environmental and technical requirements for SHP plants, led to an improvement in the technical and economic characteristics of new SHP projects. At the same time, these changes have created additional obstacles to SHP development, primarily due to the increasing cost of investment. The main barriers to SHP development at the current stage include the following:

- Issues related to reduction of water reserves due to climate change;
- Increasingly stringent technical and environmental requirements for new SHP projects;
- Due to the wide implementation of SHP in the past decades, there remain very few economically feasible sites for building new SHP plants;
- Most significantly, the 50 MW target for SHP development to 2040 has been nearly fulfilled and no new licences are likely to be issued in the near future.

At the same time, several positive factors for SHP development in Armenia exist, including:

- The high priority assigned to the development of renewable energy by the Government of Armenia in the Energy Sector Development Strategic Programme to 2040;
- Better transparency in regard to necessary requirements and documentation than in the past;
- Existence of promotional tariffs for SHP plants that are expected to cover the costs of development and ensure an adequate level of profit for investors and operators during the 15-year guaranteed purchase period;
- Relatively low interest rates for green loans offered by many Armenian banks;
- There is a consensus that some of the many existing SHP plants in Armenia suffer from problems related to age, substandard construction and poor performance of installed equipment. These issues may present an opportunity for refurbishment and upgrades on existing SHP plants.

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Azerbaijan

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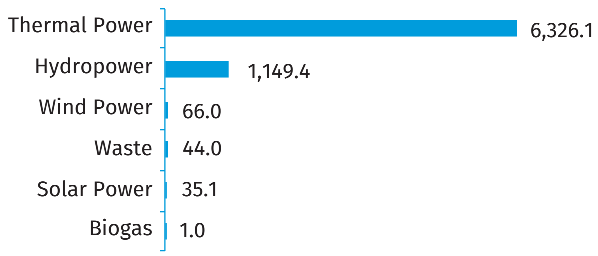
KEY FACTS

Population	10,067,100 (2020)[1]
Area	86,600 km^2[2]
Topography	The topography of Azerbaijan is primarily mountainous in the west and north of the country, while the central parts of the country, the Caspian Sea coastline in the east and much of the southern border with Iran are dominated by hills and lowlands. The highest point in the country is Mount Bazarduzu at 4,466 metres above sea level.[2,3]
Climate	Azerbaijan hosts a variety of climates across its territory and includes subtropical, semi-arid and temperate regions, with the subtropical climate being most typical. Average temperatures range between 12 °C and 16 °C but can reach highs of up to 46 °C and lows of -32 °C.[3]
Climate Change	Observed climate change in Azerbaijan since 2000 has included a rise in temperatures across the country of between 0.4 °C and 1.5 °C, as well as a decrease in precipitation of approximately 10 per cent, relative to the preceding 1971–2000 period. Climate change models predict a further increase in temperatures of 1–2 °C during the 2020–2040 period, relative to the 1971–2020 baseline.[3]
Rain Pattern	Annual precipitation averages less than 400 mm across 65 per cent of the territory of Azerbaijan, amounting to just 150–200 mm on the Absheron Peninsula but reaching as high as 1,600–1,700 in the foothills of the Talysh Mountains. Permanent snowpack exists in parts of the Greater Caucasus Mountain Range.[3]
Hydrology	There are more than 8,350 rivers in Azerbaijan, but 65 per cent of the river flow originates in neighbouring countries. The largest river in Azerbaijan is the Kura, which flows through Turkey, Georgia and Azerbaijan before emptying into the Caspian Sea and has a total length of 1,555 kilometres. The second largest is the Araz River, a tributary of the Kura, which marks the border with Turkey and Iran and has a total length of 1,072 kilometres. There are approximately 450 lakes in the country, of which the largest is Lake Sarysu, as well as 140 artificial reservoirs with a total volume of 21.5 km^3.[3]

ELECTRICITY SECTOR OVERVIEW

The installed electricity capacity of Azerbaijan was 7,621.6 MW in 2020, of which 6,326.1 MW (83 per cent) was provided by fossil fuel-fired thermal power plants, 1,149.0 MW (15 per cent) by hydropower, 66.0 MW (1 per cent) by wind power, 44.0 MW (1 per cent) by waste-fired power plants, 35.1 MW (less than 1 per cent) by solar power and 1.0 MW (less than 1 per cent) by biogas (Figure 1).

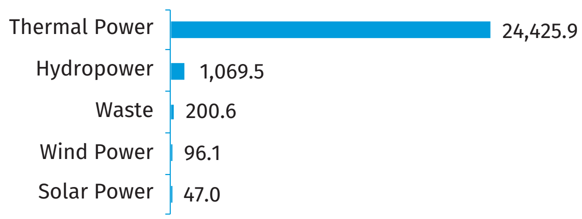
Figure 1. **Installed Electricity Capacity by Source in Azerbaijan in 2020 (MW)**



Source: State Statistical Committee of the Republic of Azerbaijan[4]

Annual electricity generation in Azerbaijan in 2020 amounted to 25,839.1 GWh, with 24,425.9 GWh (95 per cent) provided by thermal power plants, including self-producers, 1,069.5 GWh (4 per cent) provided by hydropower, 200.6 GWh (1 per cent) provided by generation from waste, 96.1 GWh (less than 1 per cent) provided by wind power and 47.0 GWh (less than 1 per cent) provided by solar power (Figure 2).

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



Source: State Statistical Committee of the Republic of Azerbaijan[4]

Access to electricity in Azerbaijan is 100 per cent.[5] Consumption of electricity in 2020 totalled 22,759.7 GWh, with the industrial, residential, and commercial and public sectors accounting for 33 per cent, 31 per cent and 25 per cent of all consumption, respectively. The agricultural, construction and transportation sectors accounted for the remaining 11 per cent. Imports of electricity in 2020 amounted to 136.5 GWh, while exports were 11.7 GWh.[4]

The electricity sector in Azerbaijan is dominated by large state-owned enterprises. The largest electricity producer in the country is Azerenergy, a state-owned company which owns and operates most generating capacities as well as the transmission grid. Azerishiq, formerly the Baku Electric Company, is another state-owned enterprise, which assumed control of the country's distribution grid in 2015. Plans to privatize some state-owned power plants were launched in 2018, with a working group established to identify facilities suitable for privatization and to attract private investors.[6,7]

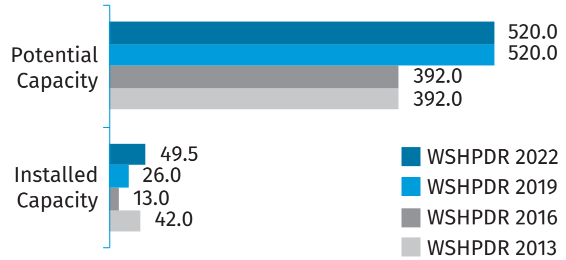
Azerbaijan is a major oil and gas exporter and the domestic electricity sector has been dominated by fossil fuel-fired thermal power plants, with hydropower and other renewable energy sources (RES) playing a secondary role. Recent development plans have targeted the refurbishment of old plants, the construction of new efficient thermal power plants in order to optimize domestic use of fossil fuels and allow an increase in exports, as well as the development of RES, in particular solar power.[7,8,9,10,11] These efforts have included the commissioning of the 409 MW Shimal-2 thermal power plant and the refurbishment of 2 220 kV and 15 110 kV substations in 2019, as well as the Aghdam-1 and Aghdam-2 substations, the Gobu substation and the 385 MW Gobu thermal power plant in 2022.[3,12]

Electricity tariffs in Azerbaijan are regulated by the Tariff (Price) Council of the Republic of Azerbaijan. Tariffs for residential consumers current as of November 2021 were 0.08 AZN/kWh (0.047 USD/kWh) for consumption of up to 200 kWh/month, 0.09 AZN/kWh (0.053 USD/kWh) for consumption of 201–300 kWh/month and 0.13 AZN/kWh (0.076 USD/kWh) for consumption of over 300 kWh/month.[13]

SMALL HYDROPOWER SECTOR OVERVIEW

Small hydropower (SHP) is defined in Azerbaijan as hydropower plants with an installed capacity up to 10 MW.[6] The total installed capacity of operational SHP plants in Azerbaijan as of 2022, excluding some SHP plants under the control of the de-facto authorities of the unrecognized Republic of Nagorno-Karabakh, was 49.53 MW, while SHP potential in Azerbaijan has been estimated at 520 MW.[6,14,15,16,17,18,19] This indicates that nearly 10 per cent of the potential capacity has been developed. Relative to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity of SHP operated by Azerbaijan increased by approximately 92 per cent as a result of territorial changes that followed the 2020 Nagorno-Karabakh War, as well as the refurbishment and construction of SHP plants.[6,14,15,16,17,18] The estimate of potential capacity has remained the same due to a lack of more recent studies (Figure 3).[6,19]

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



Source: *WSHPDR 2019*,[6] Report News Agency,[14,15] Hydropower Congress,[16] Babayeva,[17] Ministry of Energy,[18] Aghjayev,[19] *WSHPDR 2013*,[20] *WSHPDR 2016*[21]

As of the end of 2017, the total installed capacity of SHP plants operated by Azerbaijan was approximately 26 MW from 11 plants.[6] In 2019, a 300 kW mini-hydropower plant was installed on the cooling water outflow channel of the newly commissioned Shimal-2 thermal power plant, and the Oguz 1, 2 and 3 SHP plants with a combined capacity of 3.6 MW were commissioned between 2018 and 2020.[16,17,18] Following the results of the 2020 Nagorno-Karabakh War, Azerbaijan gained control of significant territories previously administered by the de-facto authorities of the Republic of Nagorno-Karabagh, as well as of 30 hydropower plants constructed on these territories over the previous few decades with a combined installed capacity of approximately 130 MW. Most of these plants were out of operation following the end of hostilities and the Government of Azerbaijan launched a programme to recommission the plants and link them to the national grid of Azerbaijan.[22,23] In 2021, the 8.0 MW Gulabird SHP plant, the Sugovushan-1 and Sugovushan-2 SHP plants with a combined capacity of 7.8 MW and the 4.0 MW Kalbajar SHP plant were recommissioned following refurbishment.[14,15] The Government plants to relaunch another 23 hydropower plants in the Kalbajar and Lachin districts, including 5 SHP plants in 2022 with a combined capacity of 27 MW.[23] A list of SHP plants operated by Azerbaijan as of 2022 is displayed in Table 2.

The technically feasible potential capacity of SHP plants in Azerbaijan has been estimated at 650 MW and the economically feasible potential at 520 MW.[6,24] The latter figure is considered official by the Ministry of Energy of Azerbaijan as of 2022.[19] However, with the inclusion of non-operational SHP plants in the Kalbajar and Lachin districts, the actual potential may be higher.

Table 2. **List of Small Hydropower Plants Operated by Azerbaijan in 2022**

Name	*Capacity (MW)*
Gulabird	8.00
Vayxir	5.00
Sugovushan-1	4.80
Mughan	4.05
Kalbajar	4.00

Name	*Capacity (MW)*
Oguz 1, 2 and 3	3.60
Goychay	3.10
Chichakli	3.00
Sugovushan-2	3.00
Shekii	1.88
Astara	1.70
Ismayilli-1	1.60
Ismayilli-2	1.60
Balakan-1	1.50
Arpachay-2	1.40
Qusar	1.00
Shimal-2 SHP	0.30
Total	**49.53**

Source: *WSHPDR 2019*,[6] Report News Agency,[14,15] Hydropower Congress,[16] Babayeva,[17] Ministry of Energy[18]

RENEWABLE ENERGY POLICY

The Government of Azerbaijan is heavily invested in developing the RES capacity of the country, among other reasons, as a means to free additional oil and gas resources for export and build international ties. In 2017, Azerbaijan made a significant step in transitioning towards RES development by committing to a 35 per cent reduction of greenhouse gas (GHG) emissions by 2030 as part of the Paris Climate Agreement in 2017, and expanded this commitment to a 40 per cent reduction of GHG emissions by 2050 at the COP26 conference in 2021.[25] The Ministry of Energy has set a target of reaching a 30 per cent share of RES in total electricity generation by 2030, aiming to achieve this goal through commissioning an additional 440 MW in RES capacities in 2023, 460 MW in 2023–2025 and 600 MW in 2026–2030.[12,25]

Over the course of 2021–2022, activity in the RES sector of Azerbaijan accelerated rapidly. In 2021, the Government of Azerbaijan signed agreements with Masdar of the United Arab Emirates for the construction of a 230 MW solar power plant in the Absheron district and with BP for the construction of a 240 MW solar power plant in Zangilan and Jabrail. In January 2022, the Saudi company ACWA Power commenced construction of the 240 MW Khizi-Absheron wind power plant, which is to be completed by 2023. As of 2022, memorandums of understanding on other RES projects have been signed with a total of 11 major companies, including Masdar, ACWA Power, BP, Total, Equinor and others.[12]

This activity was supplemented by long-awaited legislative changes providing a regulatory framework for RES development and incentives for RES projects, including the Presidential order Azerbaijan 2030: National Priorities for Socio-economic Development and the Law on the Use of Renewable Energy Sources in the Production of Electricity (Law on Renewable Energy), both adopted in 2021.[25,26] In particular, the Law on Renewable Energy provides for a guaranteed purchase tariff for RES projects, with the tariff to be either determined at auctions or through direct negotiations with the Ministry of Energy.[25] Additional incentives provided by the Law on Renewable Energy include:

- Guaranteed offtake of generated electricity;
- Guaranteed connection for RES projects;
- Creation of a database of potential RES projects, to be maintained by the Ministry of Energy, that would include information on potential locations and capacities, land ownership and boundaries, population and other information relevant for RES investors.[25,26,27]

Incentives for RES development established by previous legislation additionally include a seven-year tax exemption for investors and technology parts involved in RES development, exemptions from the value-added tax (VAT) and customs duties for imports related to RES projects, a 25 per cent subsidy on RES investments from the Azerbaijan Investment Company and a long-term credit line provided by the Entrepreneurship Support Fund.[6,24]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Certain barriers exist to SHP development in Azerbaijan, including the following:

- Lack of up-to-date studies on SHP potential in the country;
- Problems with grid connections;
- Low cost of electricity due to abundant fossil fuel resources.

However, the climate for SHP development in the country could be generally described as favourable, with enabling factors including the following:

- Considerable untapped SHP potential identified in previous studies;
- Non-operational SHP plants requiring refurbishment or modernization;
- Domestic expertise and technical capacity in the SHP sector;
- Government commitments to RES development in general and to the development of SHP in particular;
- Incentives for RES development in the form of RES auctions, tax exemptions and state investment subsidies;
- Active interest on the part of international investors in RES development in Azerbaijan;
- Active development of grid capacities to keep pace with generating capacity.

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Georgia

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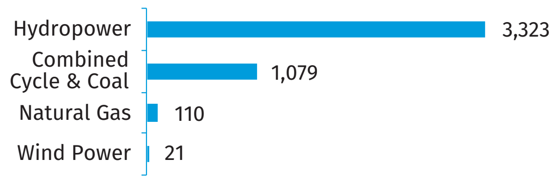
KEY FACTS

Population	3,716,900 (2020)[1]
Area	69,700 km^2 [2]
Topography	More than half of the surface area of Georgia is represented by a mountainous landscape located at an altitude of 1,000 metres or above. Most of the country's territory is located in the Caucasus Mountains and its northern border is partly defined by the Greater Caucasus Range. In addition to the Great Caucasus, other mountain ranges include the Lesser Caucasus, which runs parallel to the borders with Turkey and Armenia, and the Likhi Range, which runs from north to south dividing the country into its eastern and western regions. The highest point in the country is Mount Shkhara, which reaches 5,069 metres above sea level. The central lowlands form a structural depression on the southern slopes of the Greater Caucasus range, while the Kolkhida Lowland dominates the eastern coastline on the Black Sea.[3,4]
Climate	Western Georgia has a humid subtropical, maritime climate, while eastern Georgia has a range of climates varying from a moderately humid to a dry subtropical one. Average annual temperatures are between 14 °C and 15 °C with extremes ranging between 45 °C and –15 °C. The Black Sea influences the climate of western Georgia resulting in mild winters between December and February and hot summers between June and August. In the mountainous and high mountainous areas, temperatures range from between 6 °C and 10 °C to between 2 °C and 4 °C. The highest lowland temperatures occur in July and are approximately 25 °C, while average January temperatures over most of the region are between 0 °C and 3 °C.[2]
Climate Change	According to the country's Fourth National Communication on Climate Change to the United Nations Framework Convention on Climate Change, the process of climate change in Georgia is advancing. Compared to the period between 1956 and 1985, the annual average temperature in 1986–2015 increased in almost all regions of the country. The increase in average temperatures has varied by region, falling within the range of 0.25–0.58 °C. The country-wide average temperature increase was 0.47 °C for the latter period. Additionally, average maximum and average minimum temperatures have also shown an increasing trend in most of the regions of Georgia.[5]
Rain Pattern	Western Georgia receives heavy rainfall throughout the year totalling between 1,000 mm and 2,500 mm. The Southern Kolkhida region in the south-east of the country receives the most rain. In eastern Georgia, precipitation decreases with distance from the sea, reaching between 500 mm and 800 mm in the plains and foothills but increasing to double this amount in the mountains. The south-eastern regions receive the least precipitation in the country, with the driest period being in winter between December and February and the wettest at the end of spring in May.[2,3]
Hydrology	There are 26,000 rivers in Georgia, 99.4 per cent of which have a length of less than 25 km. More than 70 per cent of water power sources are concentrated in the five main river basins: the Rioni (22 per cent), Mtkvari (16 per cent), Inguri (15 per cent), Kodori (9 per cent) and Bzibi (8 per cent). There are also approximately 860 freshwater lakes in Georgia with a total surface area of 170 km^2.[6]

ELECTRICITY SECTOR OVERVIEW

The total installed electricity capacity of Georgia in 2021 was 4,533 MW. This comprised hydropower (3,323 MW), combined cycle and coal thermal power plants (1,079 MW), natural gas (110 MW) and wind power (21 MW) (Figure 1).[7]

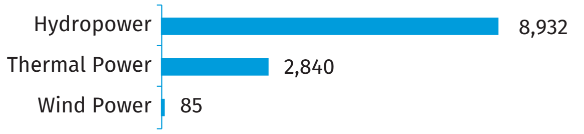
Figure 1. **Installed Electricity Capacity by Source in Georgia in 2021 (MW)**



Source: GSE[7]

In 2019, total electricity generation reached 11,856.8 GWh, over 75 per cent of which was provided by 93 hydropower plants. Seven of these plants were regulatory, providing 56 per cent of all generation from hydropower and 42 per cent of total generation. Nineteen hydropower plants operate on a seasonal basis, contributing approximately 28 per cent of total generation, while 67 deregulated hydropower plants contributed approximately 6 per cent. The remaining electricity was provided by four thermal power plants and one gas turbine (24 per cent of total generation) and one wind power plant (0.7 per cent of total generation) (Figure 2).[8] Imports of electricity in 2019 equalled 1,626.5 GWh, 68 per cent of which came from Azerbaijan and 32 per cent from Russia.[8]

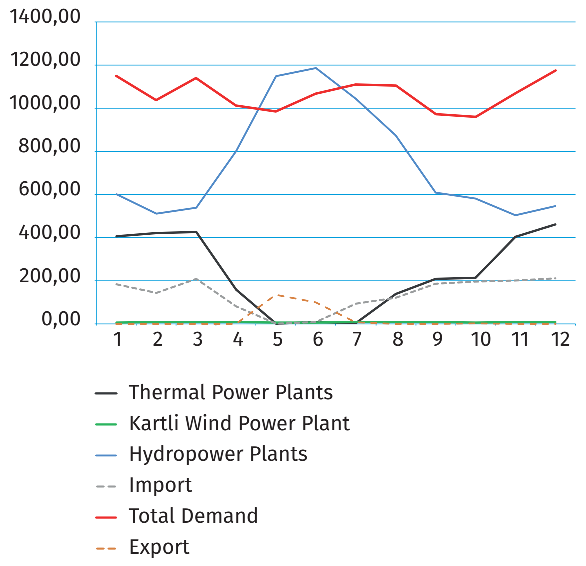
Figure 2. **Annual Electricity Generation by Source in Georgia in 2019 (GWh)**



Source: ESCO[8]

Electricity consumption in 2019 reached 13,144.7 GWh.[8] Due to fluctuations in precipitation, which affect hydropower generation, Georgia is both an importer and exporter of electricity. From May to June 2019, hydropower alone not only satisfied domestic demand but also supported the export of 234.3 GWh of electricity. However, outside of the May–June period, available capacity was not able to meet peak demand and nearly half of the total electricity supply came from thermal power plants and imports (Figure 3).[8] Currently Georgia is a net importer of natural gas and petroleum products, which, together with hydropower and biomass for residential heating, are the main energy sources. Access to electricity in Georgia is 100 per cent.[9]

Figure 3. **Electricity Balance in Georgia in 2019 (GWh)**



Source: ESCO[8]

Georgia has significantly liberalized the electricity market and implemented legislative revisions that have allowed the private sector to largely take over operations via privatization. Four key state institutions operate in the Georgian electricity sector. The Ministry of Energy is the policymaker responsible for the development and implementation of energy policy, environmental safety, the creation of a competitive environment through efficient market regulation, approval of annual energy balances and participation in the approval of strategic projects. In December 2017, the Ministry of Energy was officially merged with the Ministry of Economy and Sustainable Development. Therefore, the Ministry of Economy and Sustainable Development became the legal successor of the former.[10]`The Georgian National Energy and Water Supply Regulatory Commission (GNEWSRC) is the independent regulatory body whose main functions include: licensing in the energy sector, setting and regulation of tariffs (including for generation, transmission, dispatch and distribution), monitoring of the quality of services provided by licence holders and dispute resolution. The GNEWSRC is also authorized to impose sanctions for regulatory breaches.[11]

The Electricity System Commercial Operator (ESCO) is the commercial operator responsible for balancing the market, ensuring grid stability, conducting export/import operations to meet systemic and emergency demand and managing a unified database of wholesale energy purchase and sale (including the creation and management of a unified reporting registry). According to the Electricity Market Rules, licensed suppliers of electricity and any direct (eligible) consumers of electric power (currently some of the largest wholesale consumers) may enter into short- or long-term direct contracts for the sale and purchase of electricity. ESCO, while balancing the market (i.e., taking away surplus and filling the deficit at any particular moment), is eligible to trade non-contracted electricity and guaranteed capacity based on market-defined pricing mechanisms. It supplies dispatch licensees with the information required to carry out supply and plan consumption.[12]

Finally, the Georgian State Electrosystem (GSE) is the owner and operator of the transmission system and the sole dispatch licensee. Its main function is technical control and supervision over the entire electric system to ensure an uninterrupted and reliable electricity supply. It only has the right to purchase electricity to cover transmission losses. GSE also owns and operates part of the high-voltage transmission grid and interconnection lines with neighbouring countries.[13] Two distribution companies provide most of the retail sales: Telasi JSC, covering the region in and near Tbilisi; and Energo-Pro Georgia JSC, covering Central and Western Georgia and the eastern part of Georgia, excluding the regions of South Ossetia and Abkhazia.

Georgian legislation allows retail consumers totalling above 7 GWh in annual electricity purchases to negotiate agreements with electricity producers and importers. There are six qualified retail consumers and each purchases electricity directly from electricity producers.

As of January 2021, tariffs (exclusive of VAT) for selling electricity generated by regulated hydropower producers in Georgia varied widely, between 0.004 USD/kWh (0.013 GEL/kWh) for the Vartsikhe-2005 LTD and 0.031 USD/kWh (0.106 GEL/kWh) for the Khrami 2 hydropower plant. For thermal power plants, tariffs (exclusive of VAT) varied between 0.030 USD/kWh (0.103 GEL/kWh) and 0.046 USD/kWh (0.157 GEL/kWh) as of March 2021.[14] Newer plants generally receive a higher tariff than older ones. Enguri and Vardnili are the largest state-owned hydropower plants, generating on average 34 per cent of total electricity generation and 45 per cent of hydropower generation. The guaranteed capacity payments are collected by ESCO from all consumers and exporters in proportion to their consumption or export. Electricity consumption tariffs for the subscribers of Telasi JSC and Energo-Pro Georgia are shown in Table 1.

Table 1. **Electricity Consumption Tariffs in Georgia in 2021**

	Telasi tariff inclusive of VAT	*Energo-Pro tariff inclusive of VAT*
	By voltage level	
220/380 V (non-residential)	0.329 GEL/kWh (0.085 USD/kWh)	0.320 GEL/kWh (0.097 USD/kWh)
3.3-6 – 10 kV	0.296 GEL/kWh (0.076 USD/kWh)	0.309 GEL/kWh (0.094 USD/kWh)
35 – 110 kV	0.274 GEL/kWh (0.07 USD/kWh)	0.283 GEL/kWh (0.086 USD/kWh)
	By consumption level	
< 101 kWh	0.180 GEL/kWh (0.046 USD/kWh)	0.177 GEL/kWh (0.054 USD/kWh)
101 – 301 kWh	0.221 GEL/kWh (0.057 USD/kWh)	0.217 GEL/kWh (0.066 USD/kWh)
> 301 kWh	0.265 GEL/kWh (0.068 USD/kWh)	0.262 GEL/kWh (0.079 USD/kWh)

Source: Energo-Pro Georgia JSC,[15] Telasi JSC[16]

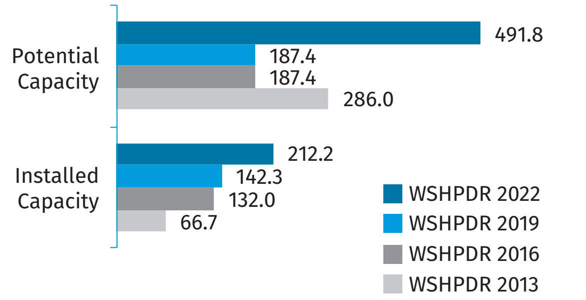
The main objective of the Government's energy policy is to improve the country's energy security. Other objectives include the diversification of energy sources, optimal utilization of local resources including renewable energy, increase of the compatibility of the country's legislative and regulatory framework with that of the European Union (EU) and the development of an energy market and an improved energy trading mechanism. Additionally, the energy policy aims to strengthen the role of Georgia as a regional energy transit point and platform for clean energy generation and trade and will be pursued through an integrated approach to energy efficiency, taking into consideration environmental issues and protection of consumer interests. The main focus of the long-term energy policy is to attract foreign investment for the construction of new power plants. Given the potential for high-capacity electricity generation and the increasing energy demand, an additional long-term objective is the construction and rehabilitation of connecting infrastructure that would enable export of surplus power to neighbouring countries.[17,18]

The Georgian electricity sector has faced many changes in recent years. In 2017, the Minister of Energy signed the protocol of the country's accession to the Energy Community Treaty, thus, signalling readiness to implement a reform of the energy trading system and develop competitive energy markets. The signing of the Treaty triggered legislative changes aimed at harmonizing with the EU market. In December 2019, the Georgian Parliament approved the Law of Energy and Water Supply, which describes in detail the functioning of the energy market.[17] On 16 April 2020, the Electricity Market Concept Design was approved, which takes into account the stages of market opening and the basic principles of the transition process. In accordance with the Concept, a Day-Ahead Market (DAM)/Intra-Day Market (IDM) operator, as well as a Balancing Market (BM) operator was formed in the wholesale segment. The Georgian National Energy and Water Regulatory Commission (GNERC) approved rules for both of these markets. The reform is intended to develop a market guided by the EU internal market principles: competition, transparency, non-discrimination and sustainability.[19,20]

SMALL HYDROPOWER SECTOR OVERVIEW

According to the Law on Energy and Water Supply of 2019, small hydropower (SHP) in Georgia is defined as hydropower plants with an installed capacity of less than 15 MW. These are termed deregulated plants on the basis that plants with an installed capacity of less than 15 MW have the right to operate without a licence, requiring only a construction permit and an environmental permit and sell generated electricity directly to consumers.[21]

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



Source: *WSHPDR 2016*,[6] GSE,[7] *WSHPDR 2013*,[22] *WSHPDR 2019*[23]

Note: Data for SHP up to 10 MW.

As of 2021, the total installed capacity of SHP plants of less than 15 MW was 262.98 MW, 212.18 MW of which was from plants of up to 10 MW.[7] Based on the feasibility studies carried out for ongoing and planned SHP projects, the total known potential capacity of SHP in Georgia (including currently installed capacity) is estimated at 491.78 MW for plants of less than 10 MW capacity and 723.88 MW for plants of less than 15 MW.[7] These data suggest that approximately 36 per cent of the known SHP potential for plants of less than 15 MW and 43 per cent of the SHP potential for plants of less than 10 MW has been developed. Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity of SHP up to 10 MW increased due to the commissioning of new plants and the potential capacity increased based on new data made available (Figure 4).

In 2019, there were 67 SHP plants (less than 13 MW as per the old definition) in operation, all of which were privately owned and many of them in need of refurbishment. In 2019, they generated approximately 655 GWh of electricity, accounting for 13 per cent of total hydropower generation for that year.[8] As of early 2021, there were 72 SHP plants in operation in Georgia, based on the new definition of SHP of up to 15 MW, of which 68 were under 10 MW.[7] The most recently commissioned SHP plants are shown in Table 1.

Table 1. **List of Selected Recently Commissioned Small Hydropower Plants in Georgia**

Name	*Installed capacity (MW)*	*Number of units*	*Type*	*Launch year*
Maksania	0.5	-	Run-of-river	2017
Nabeglavi	2.0	2x1	Run-of-river	2017
Kintrisha	5.5	2x2.75	Run-of-river	2017
Shilda 1	1.2	1x1.2	Run-of-river	2018
Kasleti 2	9.1	2x4.55	Run-of-river	2018
Kheor	1.5	1x1.48	Run-of-river	2018
Bodorna	2.5	1x2.5	Run-of-river	2018
Jonouli 1	1.9	1x1.85	Run-of-river	2018
Skurididi	1.3	1x1.33	Run-of-river	2018
Aragvi 2	2.0	1x1.95	Run-of-river	2019
Oro (Zemo orozman)	1.1	1x1.12	Run-of-river	2019
Avani	3.5	2x1.75	Run-of-river	2019
Sashuala 2	5.0	1x5	Run-of-river	2020
Ifari	3.0	2x1.49	Run-of-river	2020
Khelra	3.4	2x1.69	Run-of-river	2020
Dzama	0.8	2x0.41	Run-of-river	2020
Lakhami 2	9.5		Run-of-river	2020
Skhalta 1	9.0		Run-of-river	2020
Sashuala 1	7.5		Run-of-river	2020
Lakhami 1	6.4		Run-of-river	2020

Source: GSE[7]

Note: The plants Lakhami 1, Skhalta and Sashuala 1 listed in the source as planned had been commissioned and were operational as of early 2021.

Furthermore, 27 SHP projects (up to 10 MW) with a combined installed capacity of 114.55 MW were in the licensing and construction phase as of December 2020 (Table 2) and a further 47 projects with a combined capacity of 173.53 MW were in the feasibility study stage.[7]

Table 2. **List of Selected Ongoing Small Hydropower Projects in Georgia in 2020**

Name	*Estimated installed capacity (MW)*	*Estimated annual generation (GWh)*	*Plant type*	*Developer*	*Development stage*
Nakra	7.50	35.20	Run-of-river	LLC Aquahydro	Licensing and construction
Lopota 1	5.90	33.40	Run-of-river	LLC Artana Lopota	Licensing and construction
Khadori 3	5.40	27.50	Run-of-river	LLC Alazani Energy	Licensing and construction
Samkuristskali 1	4.80	25.70	Run-of-river	LLC Feri	Licensing and construction
Rachkha	3.03	11.46	Run-of-river	LLC GN Electric	Licensing and construction

Source: GSE[7]

RENEWABLE ENERGY POLICY

In 2013, the Government of Georgia set forth a legislative initiative (Resolution of Government of Georgia No. 214 of 21 August 2013) in order to facilitate sustainable development of the country's renewable energy potential. This initiative regulates procedures and rules of expression of interest for construction, ownership and operation of power plants in Georgia.[24]

The Energy Reforms and International Relations Department of the Ministry of Economy and Sustainable Development of Georgia is actively working on the development of the country's energy efficiency and renewable energy policy in collaboration with the European Bank for Reconstruction and Development (EBRD), the Energy Community Secretariat (EU4Energy programme), the Government of Denmark (DENEP II), KfW and other donor organizations. In 2016, the National Action Plan for the Implementation of the Association Agreement between Georgia on the one hand and the EU and the European Atomic Energy Community and their Member States on the other, as well as the Association Agenda between Georgia and the EU, were approved by Decree No. 382 of the Government of Georgia of 7 March 2016.[25]

According to the Decision of the Ministerial Council of the Energy Community (Decision 2016/18/MC-Enc), in October 2016 Georgia accessed the Energy Community as a Contracting Party. The Treaty means that the Government of Georgia has committed to implement the relevant EU rules on energy, environment and competition.[23,25]

With the joint effort of the Government of Georgia and the relevant EU authorities (EU Commission, EBRD, Energy Community Secretariat, etc.), the relevant legislative framework encapsulating three key laws (Law on Energy Efficiency, Law on Energy Efficiency of Buildings, Law on Energy Labelling) has been developed, based on the EU Energy Efficiency acquis. In December 2019, the Government of Georgia approved the National Energy Efficiency Action plan 2019–2020 (NEEAP), intended to implement the core principles of the EU energy efficiency legislation and reflecting the legislative framework developed at earlier stages.[21] In 2020, the Eastern European Energy Efficiency and Environment Partnership (E5P) Contributors Assembly approved EUR 2.6 million (USD 3.1 million) in grants in order to support project implementation in Georgia by the Nordic Environment Finance Corporation (NEFCO), which refers to energy efficiency improvement in public schools in mountainous regions of the country.[26]

In 2010, 16 Georgian municipalities joined the EU initiative Covenant of Mayors, committing to reduce CO_2 emissions by 20 per cent by 2020. A total of 24 Georgian cities are signatories of the Covenant of Mayors and are participating in the programme. Ten cities have developed Sustainable Energy Action Plans (SEAPs) defining various energy efficiency and renewable energy measures for the priority sectors: transport, infrastructure, building, street lighting, land-use changes and waste management. The major provisions of the SEAPs include support for renewable energy utilization at a local level, development of heating and cooling of public buildings based on renewable energy sources, development of electric public transport and introduction of solar photovoltaic (PV) systems for streets.[27]

The latest amendments of the Law on Electricity and Natural Gas of Georgia encourage the purchase and construction of micro-power plants (up to 500 kW). The customers will have a possibility to generate electricity, use it and sell the surplus to the grid at the cost established by GNERC.[28]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

The regulations of the Georgian hydropower sector offer potential investors many advantages. Newly built hydropower plants remain the exclusive property of investors through a Build–Operate–Own (BOO) scheme. The electricity generated by SHP plants with capacity up to 15 MW may be used by the developer for their own needs. If it is possible to connect to the local grid, the produced electricity may be exported via the local distribution network based on an agreement with ESCO or with the local distribution companies that deliver electricity directly to the client. It is nearly always financially advantageous to consume as much of electricity as possible on site and only export the surplus into the network. Between 1 September and 1 May each year, within the scope of a direct agreement made in compliance with standard conditions, the highest tariff is based on the thermal power plant electricity sold to ESCO. In the same period, the adjustable fixed tariff based on hydropower is the lowest tariff established by GNERC. Small capacity power plants may purchase electricity for the purpose of ensuring the relevant execution of the agreement on electricity generated by such plants; however, the volumes should not exceed the framework of the forecasted electricity volumes proposed (capacity).[21]

If SHP plants produce electricity for export to the local network, early discussions with the local distribution companies are needed to specify the system protection, metering equipment and the technical requirements. They will also provide an estimate of connection costs and the best location to connect to their system.[21]

The development of hydropower plants, including SHP, is regulated by the following legislation:

- Law of public and private collaboration (the public-private partnership law) of 1 July 2018 and the Government's Resolution No. 426 of August 2018 on public and private collaboration in project development and implementation. These pieces of legislation enable a company to request a guaranteed electricity purchasing tariff through a power purchase agreement.[29]
- The Government's Resolution No. 515 of 31 October 2018 on renewable energy power plants' techno-economic studies, construction, ownership and operation. The resolution is specifically focused on regulating renewable energy projects that are not launched under the public-private collaboration framework and many have already been submitted to the Ministry of Economy and Sustainable Development under Resolution No. 515 following its adoption.[30]
- The Government's Resolution No. 403 of 2 July 2020 on the support schemes for production and usage of energy from renewable resources, including hydropower. The resolution applies only to hydropower plants of more than 5 MW capacity and provides regulations defining the support period and conditions for the disbursement of a bonus tariff.[31]
- The Government's Resolution No. 257 of 31 May 2019, which defines the procedure for issuing permits for the construction of facilities of special importance and the permit conditions.[32]
- The Government's Resolution No. 890-IIs of 1 June 2017, which defines the Environmental Assessment Code. According to this resolution, SHP plants of up to 2 MW capacity are exempt from undergoing an environmental impact assessment (EIA).[33]

During the licensing stage, the project is initially submitted to the Ministry of Energy and Sustainable Development, where it is reviewed by the Department of Energy Policy and Investment Projects, which prepares a report card for the Deputy Minister. At this point the preparation of the contract for the project begins with the decision and assignment of the Deputy Minister. Subsequently, the prepared draft contract is sent to the Ministry of Justice, the Ministry of Finance and the Public and Private Partnership Agency. Following discussions, the Government issues an ordinance and a contract is signed based on that ordinance.

Initiating construction is possible prior to receiving the licence and is referred to as the construction-licensing stage. Construction permits are issued by the Technical and Construction Supervising Agency (TACSA, part of the Ministry of Energy and Sustainable Development) and regulated by Resolution No. 257.[32,34]

COST OF SMALL HYDROPOWER DEVELOPMENT

The cost of construction of SHP plants in Georgia per MW ranges from USD 1 million to USD 2 million. The reference tariff is approximately USD 0.055 per 1 kWh of generation. The payback period also varies from project to project and is generally between 6 and 10 years. A detailed study on the cost of SHP development in Georgia was carried out in 2015 by the Norwegian Water Resources and Energy Directorate in collaboration with the Ministry of Energy of Georgia. The study prepared price curves for SHP plants of several common turbine types (including Pelton, Francis and Kaplan/bulb turbines) and for capacities of 1–13,000 kW. According to the study, typical prices ranged between approximately USD 1,520 and USD 4,738 per kW for low-head (5–20 metres) installations and between USD 275 and USD 870 per kW for high-head (100–600 metres) installations.[35] Estimates of investment costs of some SHP projects are shown in Table 3.

Table 3. **Estimates of Investment Costs of Small Hydropower Projects in Georgia**

Name	*Installed capacity (MW)*	*Estimated investment cost (USD)*	*Developer*
Samkurists-kali 1	4.8	6,500,000	LLC Feri
Lakhami 2	9.5	14,790,000	LLC Austrian Georgian Development
Nakra	7.5	9,600,000	LLC Aquahydro
Lopota 1	5.9	8,200,000	LLC Artana Lopota
Khadori 3	5.4	6,200,000	LLC Alazani Energy
Goginauri	4.7	1,300,000	LLC ALTER ENERGY
Rachkha	3.0	13,612,290	LLC GN Electric
Dvirula	2.0	2,620,000	LLC DM Energy
Khrami	1.1	1,100,000	LLC New Technology 2014
Tbilisi sea	0.6	630,000	LLC Aqua Energy Georgia

Source: GSE[7]

Most of the financing of SHP projects is done by commercial banks, based on the principle of 30 per cent equity/70 per cent loan. There are also projects fully funded by foreign organizations and foundations.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

The impact of the climate crisis on SHP in particular has not yet been investigated in Georgia. The latest national communications of Georgia were focused on the impacts of the climate crisis on large hydropower plants (such as the Enguri plant). According to the Third National Communication (NC3) of Georgia on Climate Change, average annual temperature in the Upper Svaneti region, which includes the upper part of the Enguri River basin, is expected to increase by 3.7 °C by 2100 compared to the average for the period 1986–2010. The temperature increase is in turn expected to impact the geometrical dimensions of glaciers as well as the glacial runoff in the Enguri River basin. At the current pace of temperature increase, the entire Caucasus Range is expected to be free of ice cover by 2150–2160. The NC3 projects that glacial degradation in the Enguri River basin will lead to a 40 per cent decrease in glacial runoff by 2100, relative to 2010, and a corresponding 13 per cent decrease in annual runoff in the Enguri River itself by 2100, relative to the levels recorded during the mid-20th century.[36]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The key barriers to SHP development in Georgia include:

- High initial costs;
- Lack of continually renewed hydrological information;
- Absence of local manufacturing capacity in Georgia, with the exception of a few workshops producing cross-flow (Banki) turbines;
- Lack of financial incentives from international organizations and local banks;
- Lack of tax initiatives or feed-in tariff regimes;
- Cancellation of promising policies, such as concluding long-term power purchase agreements with renewable energy producers;
- Possible decrease in overall hydropower potential in the long-term due to the ongoing climate crisis.[21,29]

The key enabler for SHP development in Georgia is the opening of the electricity market, which will allow generation units operating in Georgia to bid on the DAM/IDM/BM and increase their income, as well as set the real price for electricity in the country. Transparency in pricing is also expected to attract investments. Due to the low marginal cost of electricity for SHP plants, they will be able to recoup their costs quickly and become profitable. Other significant benefits from the new market model are expected to occur:

- Improved system reliability due to provision of sufficient notice for plants to be scheduled;
- Encouragement of the participation of new market players;
- Creation of an arbitrage opportunity between the DAM and the BM, increasing liquidity.

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Iraq

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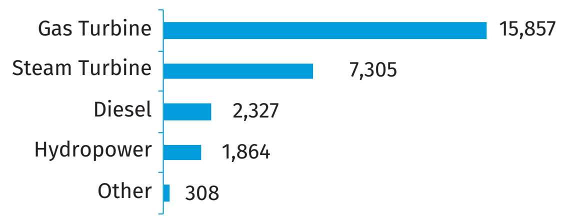
KEY FACTS

Population	40,222,503 (2020)[1]
Area	437,072 km² [2]
Topography	Iraq has four topographical regions: the alluvial plains in the centre and south-east covering almost one third of the country and characterized by low elevations (below 100 metres); an upland region in the north between the Tigris and Euphrates Rivers with the highest peak reaching 1,356 metres; deserts in the west and south rising to elevations above 490 metres; and the highlands in the north-east with an average elevation of 2,400 metres. The highest point, Ghundah Zhur, lies near the border with Iran border and reaches 3,607 metres.[3]
Climate	The climate of Iraq is hot and dry and is impacted by the country's position between the subtropical aridity of the Arabian Desert and the subtropical humidity of the Persian Gulf. The coldest month is January, with temperatures ranging from 5 °C to 10 °C, while the warmest month is August, with temperatures reaching 30°C and higher. Summers in most parts of the country are mild to hot, with abundant sunshine, but heavy humidity predominates around the southern coast on the Persian Gulf. Summer temperatures can easily reach 45 °C or more, particularly in desert areas. Hot, dry desert winds may be quite powerful at times, causing violent sandstorms.[4]
Climate Change	Expected climate change impacts in Iraq include an increase in maximum temperatures of 0.5–2.5 °C and an increase in minimum temperatures of 0.2–1.8 °C across the country by the end of the 21st century, relative to the 1979–2018 baseline period. The hot arid desert climatic zone predominating in much of the country is expected to shift further northwards by 2071–2090, displacing large areas of the Iraqi arid steppe.[5,6]
Rain Pattern	Average annual precipitation in the lowlands ranges between 100 mm and 180 mm, with most of the rainfall occurring between November and April. In the foothills of the north-east, annual precipitation ranges from 300 mm to 560 mm, while in the mountains it can exceed 1,000 mm, mainly in the form of snow.[3]
Hydrology	The three major river basins in Iraq are the Tigris, the Euphrates and the Shatt Al-Arab. The average annual flow of the Euphrates River at the Iraqi border is estimated at 30 km³, whereas that of the Tigris River is estimated at 21.2 km³. While the Tigris receives 50 per cent of its water from the territory of Iraq, the Euphrates receives more than 90 per cent of its water from outside the country. The Tigris has a number of tributaries on its left bank, including the Greater Zab, the Lesser Zab, the Al-Adhaim and the Diyala Rivers. The rivers of Iraq have a total length of 4,773 kilometres, with the Tigris and Euphrates accounting for 1,290 kilometres and 1,015 kilometres, respectively.[7]

ELECTRICITY SECTOR OVERVIEW

The total installed electricity capacity of Iraq operated by the Ministry of Electricity (MOE) in 2019 was 27,661 MW. This total included 15,857 MW (57 per cent) provided by gas-fired power plants, 7,305 MW (26 per cent) provided by steam power plants, 2,327 MW (8 per cent) provided by diesel-fired power plants, 1,864 MW (7 per cent) provided by hydropower plants, and 308 MW (1 per cent) provided by other sources (Figure 1). However, not all existing plants were operational as of 2019, with available capacity at 22,031 MW. Additionally, average daily power output that year was only 14,064 MW due to issues with operational efficiency in the electricity sector also observed in previous years.[8,9]

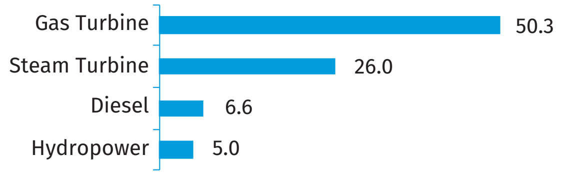
Figure 1. **Installed Electricity Capacity by Source in Iraq in 2019 (MW)**



Source: MOE[8]

Generation of electricity by power plants operated by the MOE in 2019 reached 87.9 TWh, with gas-fired power plants providing 50.3 TWh (57 per cent) of the total, steam power plants providing 26.0 TWh (30 per cent), diesel power plants providing 6.6 TWh (nearly 8 per cent) and hydropower providing 5.0 TWh (6 per cent) (Figure 2). Purchases of electricity from independent power producers (IPPs) amounted to 27.8 TWh, imports from neighbouring countries were 6.6 TWh and another 0.9 TWh were imported from the autonomous Kurdistan Region.[8]

Figure 2. **Annual Electricity Generation by Source in Iraq in 2019 (TWh)**



Source: MOE[8]

Electricity supplied to the grid in 2019 totalled 108.8 TWh, but losses accounted for 66.8 TWh (61 per cent) of the total supply, with only 42.0 TWh billed to customers. Consumption was dominated by the residential sector, which used 25.8 TWh or 61 per cent of all billed consumption, while the government sector consumed 5.2 TWh (12 per cent), the industrial sector consumed 4.7 TWh (11 per cent) and the remainder was accounted for by the commercial sector, the agricultural sector and other consumers.[8] As of 2020, access to electricity in Iraq was 100 per cent.[10]

Electricity shortages in Iraq entail major costs for the economy in the form of lost production time, damage to capital assets from power interruption and disruption of commercial processes. It is estimated that shortages of electricity cost the country's economy some USD 3–4 billion per year.[11] Furthermore, due to cold winters and extremely hot summers, power shortages also impose significant hardship on the population.

The two main providers of electricity in Iraq are the MOE and private owners of generators scattered across the country. The MOE is the principal policy maker, power producer, service provider, regulator and operator of the electricity sector in Iraq. As a result of inefficient policies, a lack of security, the burden of the military campaign against the Islamic State and the decline of oil prices, the electricity sector has been falling into decay, leading to the failure of the MOE to supply electricity 24 hours a day across the country. The unreliable power supply from the national grid has led to the widespread installation of private diesel generators and the creation of neighbourhood mini-grids. These are not regulated by the Government and their constant operation implies significant costs, as well as noise, air pollution and carbon emissions. In addition, international oil companies operating in the country constitute a third limited producer of electricity, but they produce electricity for their own use only. Generally, they are also not subject to Government regulations.[11]
In addition to the issues on the supply side of the electricity sector, challenges also exist on the demand side. These include the widespread theft of electricity, resulting in high levels of unmetered consumption and widespread non- or under-collection of bills due to the absence of an effective billing system.[11] In recognition of the need for a reform, the Government began the privatization of the electricity sector in early 2016. A multi-phase strategy was developed in consultation with the World Bank, which aims to reform the distribution sector, reduce electricity consumption by 20 per cent, curb losses and end the exploitation of consumers by the owners of neighbourhood grids. Based on the recommendations of the World Bank, the country was divided into 180 zones. Private companies will take over responsibility for distribution in each zone and ensure around-the-clock electricity supply in return for a percentage of electricity tariffs. The first projects were launched in 2016 and 2017 in Baghdad neighbourhoods and have produced positive initial results.[11]

Apart from the MOE capacities and neighborhood mini-grids, the country imports electricity from Iran via four transmission lines providing access to a combined capacity of 1,100 MW. Furthermore, the MOE purchases power from several large domestic IPPs located in the cities of Samawa, Basra and Basmaya with a total installed capacity of 470 MW, as well as from the Bazian power plant in the Kurdistan Region with a capacity of 3,120 MW as of 2021 (set to be increased to 4,500 MW). Plans exist to develop additional interconnections with Turkey and the countries of the Gulf Cooperation Council, as well as to construct several large solar power plants in southern Iraq with a total capacity of 755 MW.[12]

Electricity tariffs in Iraq for electricity purchased from the national grid are determined by consumer category, as well as by consumption category in the case of the residential and commercial sectors. While the cost of electricity production in the country was 108 IQD/kWh (0.091 USD/kWh) in 2017, electricity tariffs for end users are heavily subsidized, to over 90 per cent of the production cost.[11] Electricity tariffs current as of 2019 are displayed in Table 1.

In practice the subsidized electricity provided by the MOE is not sufficient to meet electricity demand and many people rely on purchasing additional expensive power from neighbourhood generators. The cost of a 1-ampere generator connection is 7–20 USD/month depending on the length of the daily service time, or approximately 125 IQD/kWh (0.086 USD/kWh) in the case of a 24-hour connection, with a typical family spending upwards of 300 USD/month for a 15-ampere connection. Neighbourhood generators were estimated to have generated USD 4 billion in income in 2018, or roughly the same as the capital expenditures for the entire power sector set aside in the 2019 federal budget.[12]

Table 1. **Electricity Tariffs in Iraq in 2019**

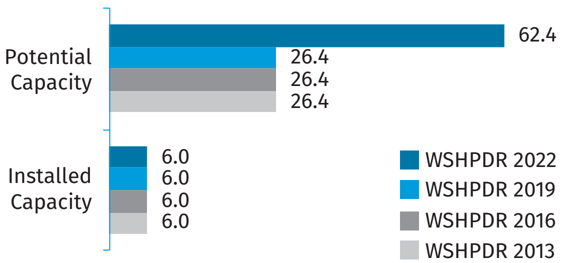
Consumption category	*Price in IQD/kWh (USD/kWh)*
Residential:	
1–1,500 kWh	10 (0.007)
1,501–3,000 kWh	35 (0.024)
3,001–4,000 kWh	80 (0.055)
≥ 4,001 kWh	120 (0.083)
Commercial:	
1–1,000 kWh	60 (0.041)
1,001–2,000 kWh	80 (0.055)
≥ 2,001 kWh	120 (0.083)
Industrial	60 (0.041)
Governmental	120 (0.083)
Agricultural	60 (0.041)

Source: MOE[8]

SMALL HYDROPOWER SECTOR OVERVIEW

There is no official definition of small hydropower (SHP) in Iraq. In the current chapter, SHP is defined as hydropower plants with a capacity of up to 10 MW. The installed capacity of SHP in Iraq as of 2019 was 6 MW, whereas the hydropower potential, including existing plants and potential sites, is estimated at 62.38 MW, indicating that approximately 10 per cent of the known potential capacity has been developed. Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity of SHP in Iraq has not changed, whereas the total potential capacity has increased 136 per cent due to a reassessment of existing data (Figure 3).[9,13,14]

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



Source: *WSHPDR 2019*,[9] Al-Kayiem & Mohammad,[13] Ameen,[14] *WSHPDR 2013*,[15] *WSHPDR 2016*[16]

Although there is no official definition of SHP in Iraq, hydropower plants with a capacity of up to 80 MW are generally classified as SHP plants. Following this definition, there are six SHP plants in the country, of which only one is below 10 MW (Table 2). The combined capacity of hydropower plants up to 80 MW is 251 MW.[14]

Table 2. **Existing Hydropower Plants up to 80 MW in Iraq**

Name	*Capacity (MW)*
Samaraa Dam	80
Mosul Regulating Dam	60
Hemrin Dam	50
Adhaim Dam	40
Al-Hindiyah Dam	15
Shatt Al-Kuffa Regulator	6
Total	*251*

Source: Ameen[14]

Total hydropower potential in Iraq is estimated to be 80,000 GWh.[9] The potential SHP capacity estimate is based on previous studies that have identified 49 prospective hydropower sites with potential capacities ranging from 5 MW to 261 MW, of which six were SHP sites within the 5–10 MW range, suggesting a minimum total potential capacity of 30 MW for these six plants (Table 3).[9,14] Besides the identified potential sites, there are also 30 non-powered barrages and water regulators that can be used for electricity generation, of which at least 12 can be used for SHP development. Their combined capacity is 26.38 MW (Table 4).[9,14]

Table 3. **Potential Hydropower Sites in Iraq by Capacity Range**

Installed capacity (MW)	*Number of sites*
5–10	6
11–20	7
21–30	5
31–50	12
51–100	12
101–150	6
> 150	1

Source: Ameen[14]

Table 4. **Potential Small Hydropower Sites in Iraq on Existing Infrastructure**

Site	*Units*	*Discharge (m^3/s)*	*Potential capacity (MW)*
Tarthar Water	4	171	5.662
Al-Abbasiya Regulator	2	168	4.683
Al-Garraf Head Regulator	4	158	3.650
Al-Btera Regulator	2	118	3.016
Al-Hilla Head Regulator	8	189	2.634
Al-Kahla Regulator	2	67	2.394

Site	*Units*	*Discharge (m^3/s)*	*Potential capacity (MW)*
Al-Sader Al-Mushtarak	3	60	1.300
Al-Khalis Regulator	1	49	0.760
Al-Diwaniya Regulator	3	49	0.755
Al-Kassara Regulator	1	24	0.601
Al-Dagara Regulator	2	31	0.508
Qal'at Salih Regulator	2	25	0.416
Total	**34**	**–**	**26.379**

Source: Ameen[14]

Since 2013, Iraq neither added nor announced additional new hydropower capacities. As such, the development of hydropower, including SHP, currently does not represent a major priority for the country's energy sector development, and it is not expected that many hydropower plants will be built in the future.

RENEWABLE ENERGY POLICY

Iraq is one of the world's most important oil producers and is among the countries with the largest proven oil reserves. Over the past years, the energy sector of Iraq has suffered due to the war and energy demand growth is now outpacing capacity expansion. Renewable energy could be used to both supply electricity to remote locations not connected to the grid and to feed into the grid. This aim was outlined in the Integrated National Energy Strategy of Iraq of 2012, which remains the country's sole policy document targeting renewable energy development.[17]

However, the development of renewable energy sources has been progressing rather slowly, hindered by the conflict with the Islamic State and other systemic factors.[17] Thus it was only in 2016 that the MOE opened the first renewable energy tender for the 50 MW Sawa solar power project in Al-Salman District.[18] The installation of solar photovoltaic (PV) panels by households has likewise made little progress in the country, in spite of the severe energy shortage in the past decade. This is due to the high installation costs for solar power compared to those for diesel generators, with the latter at just 5 per cent of the cost of installation for a solar PV system of comparable capacity.[19]

There are no further policies on renewable energy or energy efficiency. The Government is aiming to attract new foreign investors for solar and wind power projects, offering various tax exemptions and support during the licensing, approval, implementation and operation processes.[20] However, there are no universal incentives in place applicable to all renewable energy projects.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The following factors entail major barriers to the development of SHP in Iraq:
- Lack of financial resources;
- The poor condition of electricity infrastructure;
- Constantly changing plans of the Government, including frequently cancelled tenders;
- Risks associated with payments and security.

There are few, if any, enablers for further SHP development in Iraq; however, some untapped potential SHP capacity exists in the country in the form of both new sites as well as existing non-powered barrages and dams.

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Israel

Grant Pace, Chi Chen and Stafford W. Sheehan, Air Company

KEY FACTS

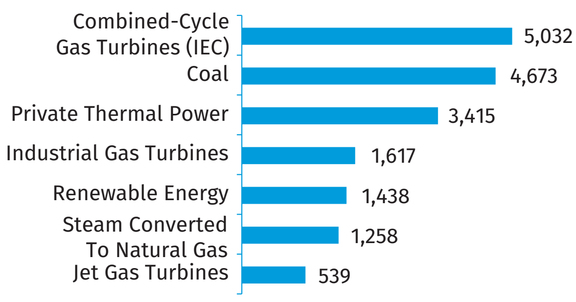
Population	9,054,000 (2019)[1]
Area	20,770 km[2]
Topography	Located within the Fertile Crescent region, Israel hosts a variety of topological features, including highlands, river valleys, Mediterranean coasts, mountains, coastal plains and deserts. At 1,208 metres, Mount Meron is the highest point in the country. Israel also features the Dead Sea, which is the lowest point on the Earth's continental surface (400 metres below sea level).[2]
Climate	Due to its diverse topography, including deserts and coasts, Israel has various climates. The coastal areas have a typical Mediterranean climate with cool, rainy winters and long, hot summers. By contrast, the southern Negev and Arava areas have hotter desert climates with milder winters and little precipitation.[2,3] Temperatures across these regions range from 11 °C in January on the Mediterranean coast to 46 °C in August in the southern City of Elat.[2] The capital, Jerusalem, is representative of the hot summer Mediterranean climate that dominates most of the country and has an average temperature of 17.2 °C.[4]
Climate Change	Due to climate change, Israel has seen an increase in the number of incidents of extreme heat waves and experiences 10 mm of sea level rise annually. By 2100, a 10 per cent decrease in precipitation is projected.[5]
Rain Pattern	Israel receives roughly 70 per cent of its rainfall between November and March, with almost no rain from June to August. Precipitation decreases with latitude: the south receives less than 100 mm of rain annually and the north receives approximately 1,100 mm of precipitation.[6]
Hydrology	The Jordan River is the longest and most notable river in Israel, flowing 251 km south through the freshwater Sea of Galilee (Lake Tiberias) and into the Dead Sea.[7] The Sea of Galilee in the north-east is the largest freshwater lake in the country, covering 166 km[2] and reaching depths up to 43 metres.[8] In the south, the Dead Sea rests at 430 metres below sea level.[9]

ELECTRICITY SECTOR OVERVIEW

In 2020, 100 per cent of the population of Israel had access to the nationalized electricity system.[10] Israel was a net importer of energy in 2019, importing approximately 259,000 GWh and exporting approximately 79,000 GWh.[11] The largest portion of this imported energy came in the form of crude petroleum from Azerbaijan, Kazakhstan and the United States.[12]

At the end of 2018, the installed electricity capacity of Israel totalled 17,972 MW, of which approximately 74 per cent (13,335 MW) was operated by the predominantly state-owned Israel Electric Corporation (IEC). Private generators, including renewable energy plants, accounted for the rest (Figure 1).[13] In 2019, the country's total installed electricity capacity is reported to have reached 19,493 MW.[14]

Figure 1. **Installed Electricity Capacity by Source in Israel in 2018 (MW)**

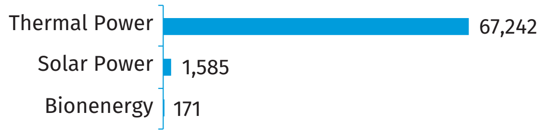


Source: Ministry of Energy[13]

Note: The capacities were calculated based on percentage values.

According to the Central Bureau of Statistics of Israel, in 2019, a total of 9,509 ktoe (110,600 GWh) of energy was produced domestically. The energy supply breakdown primarily consisted of natural gas (90 per cent). Smaller portions came from solar thermal power (4 per cent), solar photovoltaics (PV) (approx. 2 per cent), oil (approx. 1 per cent) incineration of non-renewable (approx. 1 per cent) and renewable waste (0.1 per cent) and other renewable sources (0.1 per cent).[13] Electricity supply totalled 68,998 GWh in 2018, with over 97 per cent coming from fossil fuels and the remainder from renewable energy (Figure 2). Renewable energy sources were dominated by solar power, with an unspecified amount of electricity coming from hydropower.[15] In 2019, domestic electricity generation in the country reached 72,524 GWh; however, no breakdown of generation by source is available.[14]

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



Source: IRENA[15]

Few annual days of precipitation and high sunshine would make solar power a prominent energy source; however, the success of solar energy has been significantly limited by recent discoveries of abundant offshore natural gas reserves and supply deals with Egypt. Natural gas shifted fossil fuel consumption from 65 per cent of coal and 33 per cent of natural gas in 2009 to 45 per cent of natural gas in just two years. This trend was projected to continue with an over 65 per cent share of natural gas expected by 2020.[16] However, natural gas receded to under 40 per cent of total energy supply by 2019, in part due to the overabundance of natural gas reserves in the country exceeding the demand for exports and internal usage.[11,17,18]

Unconnected to any other electricity grid, Israel is often portrayed as an electricity island. In recent years, Israel began planning pumped-storage hydropower facilities to make use of surplus electricity capacity at off-peak periods. The Israeli Public Utilities Authority has commissioned the Gilboa pumped-storage hydropower plant with a capacity of 300 MW, which is the first plant of this kind in Israel.[19,20] The commissioning of the turbines was scheduled for 2018 and the plant began operating in 2020.[21] As of 2016, a second pumped-storage hydropower plant was planned with a capacity of 340 MW, and in total the Government has a national plan for 800 MW of pumped hydropower capacity.[19] The Dead Sea Water Project, the first sea water pumped-hydropower plant with a capacity of 2,400 MW, is scheduled to be completed in 2021.[22] Additionally, a number of tidal wave projects have been developed or are under development in Jaffa Port near Tel Aviv.[23,24]

The majority of electricity in the country is provided by IEC, one of the largest industrial organizations in Israel and the sole integrated electric utility in the country. Since 2011, IEC has been operating 17 power plants (including five major thermal power plants). In June 2018, the Government approved a comprehensive structural reform in the Israeli electricity sector, to be implemented over the course of eight years (2018–2026), to decentralize IEC. The reform is aiming to lower the market share of IEC to 40–60 per cent in 2026. After the implementation of these policies to promote competition in the sector, in 2018 the share of IEC in the total installed capacity of Israel dropped to 74 per cent.[13] In 2019, IEC represented 72 per cent of the electricity market, with the remaining energy coming from individual power producers (IPPs).[17] These figures demonstrate the rapid growth of the electricity provided by private producers, whose output made up 0.5 per cent of the total supply as recently as 2009.

The Public Utilities Authority for Electricity was established in 1996 to oversee electricity tariffs under the Electricity Sector Law. Prior to the creation of the Authority, IEC itself regulated the electricity market. The Authority sets formulas that determine the rates of the tariffs without an explicit cap. Distinct electricity rates exist for residential and agricultural use, street lighting, general, bulk and time of use, but not across regions.[25] In January 2019, the cost of electricity for household consumers rose by 6 per cent to 0.49 ILS/kWh (0.15 USD/kWh).[25] The tariffs, which are based on the cost of the service, rose due to the cost of pursuing the Government's decision to increase the share of renewable energy sources and the weakening of the shekel against the US dollar, exacerbating rising fuel costs.[18]

SMALL HYDROPOWER SECTOR OVERVIEW

Israel does not have an official definition of small hydropower (SHP). For the purposes of this chapter, SHP will be defined as any hydropower plant with a capacity below 10 MW.

Since 2010, the International Renewable Energy Agency (IRENA) has reported that the capacity of SHP in Israel has been constant at 7 MW, demonstrating the lack of focus to develop SHP in Israel in comparison to other sources of clean energy.[26] This total SHP capacity comes from various unspecified power plants identified by the Israeli Ministry of Environmental Protection report in 2014. However, detailed information on these SHP plants has not been provided by the Ministry or other sources.[27] Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, the current edition is reporting a higher capacity based on more accurate data (Figure 3), however, as mentioned there has been no actual change in installed capacity. The potential for SHP development in the country remains unknown.

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

Source: IRENA,[26] *WSHPDR 2019*[28]

The SHP capacity of Israel has not grown according to official figures, despite discussion of hydropower as a means of energy diversification.[27] Regardless, this endeavour has spurred innovation, including the Benkatina turbine, a damless plant generating hydropower from municipal pipes, which was invented by engineers from Leviathan Energy.[29] Ranging from 5 kW to hundreds of kilowatts, this small turbine fits into existing piped-water systems so that it can generate electricity from the water running downhill through it while maintaining the integrity of the piping. The turbine requires low infrastructural support and is adaptable to variable flow conditions. So far, it has been installed in several locations in Israel since 2013, however, the capacity of these installations is not known. Since 2012, other hydropower technologies have also been introduced in Israel. Thus, in 2020, researchers identified 96 potential sites for closed-loop hydropower plants using geographic information system (GIS) analysis. However, the average generation potential of these sites amounts to 42.7 GWh, which exceeds the 10 MW definition of SHP. The number of the potential sites that would fall under the 10 MW threshold is not identified.[30]

RENEWABLE ENERGY POLICY

The history of promoting renewable energy research in Israel is underpinned by the goal of ensuring independence from foreign oil. While supporting solar energy research throughout the 1970s and 1980s, Israel passed the world's first legislation requiring new residential buildings up to 27 metres high to install solar water heaters in 1980. Despite the existing drawbacks in implementing renewable energy technologies in the country, this remains a major point of progress for its energy independence.[31]

In 1996, the Electricity Market Law allowed IPPs to enter the market and produce up to 20 per cent of overall electricity in the country, accelerating its transition to clean energy. As of 2017, approximately 7,516 GWh (14.5 per cent) of the electricity supplied to customers by IEC was purchased from private producers, compared to 6,753 GWh in 2016.[16]

Israel entered the United Nations Framework Convention on Climate Change in 1996. In 1998, the country signed the Kyoto Protocol and committed to the development of alternative energy to reduce foreign fossil fuel dependence and mitigate pollution. Despite a track record of policy promoting renewable energy, Israel was almost entirely reliant on fossil fuels until 2002.[32]

Decision No. 2664 of November 2002 encouraged the construction of new renewable energy power plants by private electricity producers. Between 2002 and 2007, several solar-thermal units and solar PV power plants were built and began operating. In 2007, the National Infrastructures Ministry, which later became the Energy and Water Resources Ministry, set a new goal for a 20 per cent energy consumption reduction by 2020. A five-year research and development plan aiming at the promotion of the renewable energy sector through funding, international collaboration, professional training programmes and tax benefits began in 2008. A plan for constructing three solar power plants and a goal of a 10 per cent share of renewable energy production by 2020 was set by Government Decision No. 4450. The acceleration of solar power deployment was further supported in January 2010 when the National Planning and Building Council approved the Solar Energy Planning Strategy, which supported medium to large solar fields and rooftop PV panels. The Energy and Water Resources Ministry published a new renewable energy policy to ensure the implementation of Government Decision No. 4450's goal of 10 per cent of electricity to be produced by renewable sources by 2020, but as of 2018, the share of renewable energy, at less than 3 per cent, was far from reaching this goal.[15,32]

In 1996, a new entity (the Israeli Public Utility Authority, or PUA) was formed to monitor tariffs and costs of IEC. Starting in 2009, feed-in-tariffs (FITs) for solar PV and wind power technology became available, with small-medium wind power plants (up to 50 MW) receiving up to 1.60 ILS/kWh (0.45 USD/kWh) and with residential and industrial solar power plants (up to 60 MW) receiving between 1.07 and 2.01 ILS/kWh (0.30–0.56 USD/kWh). In 2013, these tariffs were closed and ultimately replaced by a net metering system.[33]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

Israel set a goal of reaching a 10 per cent share of renewable energy in electricity generation by 2020 and has focused on policy-based support for solar power. However, the Ministry of Finance only outlines support for developing solar power, wind power and waste-based electricity generation, not hydropower, let alone SHP.[34] Furthermore, the 2012 Long-Term Master Plan for the National Water Sector of the Water Authority states that hydropower will be promoted via market forces, suggesting that there is no long-term plan for policy-based incentives for SHP.[35]

COST OF SMALL HYDROPOWER DEVELOPMENT

Though an unspecified, but likely large, share of the capacity of these projects would not be classified as small-scale, an analysis of 96 potential closed-loop off-river hydropower sites in Israel found that 11 per cent of these projects would cost under USD 577,000 per MW for power and storage components, with 35 per cent costing double the amount.[30] Israel is currently expected to spend over USD 1 billion for its joint Dead Sea water project with Jordan.[36] With inexpensive natural gas available and solar power prices falling in part due to policy emphasis, the relative abundance of high-cost hydropower projects helps explain its lack of development and focus from the Government.

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

Due to the prioritization of other renewable energy sources more suited to the country's climate, little explicit support for hydropower exists, let alone SHP, which is not defined by the Government. However, projects such as the Benkatina turbine have received funding from the Ministry of Trade and Labour's Eureka programme.[29] The company that invented the Benkatina turbine also demonstrates the role of maximizing the potential of local funding, such as through the Negev-focused Mack Ness Fund, which supports projects promoting population growth and economic development in the Negev region.[38] Utilizing localized funding sources such as the Mack Ness Fund may be a viable option for future SHP development as hydropower viability varies greatly by region within the country.

EFFECT OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

The projected decline in precipitation due to the climate crisis further discourages SHP development in Israel, which is already burdened by uneven and limited rainfall.[5] Decreased precipitation also makes solar power, which is already receiving a stronger policy support, a more viable option due to the country's climate. Additionally, little attention is currently paid in Israel to wave-based hydropower and impending rising sea levels may further discourage its future consideration.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The key factors limiting SHP development in Israel include:

- Unequal distribution of precipitation, both throughout the country and throughout the year;
- Low natural gas prices and the near-monopoly of the state (IEC) in the electricity sector;
- The high cost of solar and wind farms relative to natural gas limits the viability of pumped hydropower energy storage, despite of the advantage that it can be paired well with solar and wind power to store intermittent energy during off-peak times;
- Policy support for renewable energy focuses primarily on solar power due to precipitation trends limiting hydropower;
- Although several hydropower projects are operating or are currently under construction, the majority of them exceed standard definitions of SHP and proposed projects tend to favour larger capacities.

At the same time, the following enablers for SHP development can be identified:

- Nearly 100 new closed-loop, off-river hydropower sites totalling over 4,000 GWh of potential were recently identified, demonstrating that novel approaches to conceptualizing hydropower can increase the SHP potential of Israel;
- As intermittent solar and wind power utilization increases due to Government-promoted development, pumped hydropower storage becomes increasingly viable. The construction of new plants in recent years is a testament to this. Thus, even renewable energy policies not explicitly focused on SHP may diminish barriers to its implementation;
- The impact of the legislation that adopted solar water heaters towards reducing energy consumption from non-renewable sources has demonstrated that highly distributed energy generation approaches can be successful in Israel;
- The strong desire to reach independence from foreign fossil fuel imports may provide leverage for further promotion of SHP as a domestic energy source;
- Innovative SHP technologies, such as those utilized by the Benkatina turbine and closed-loop off-river plants, represent technical promise for future enablers of SHP deployment.

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Jordan

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KEY FACTS

Population	10,550,000 (2019)[1]
Area	89,342 km² [2]
Topography	Jordan has a diverse topography ranging from mountains to dry desert and can be divided into three main geographic regions: 1) the Jordan Valley region (i.e., the Ghor), in which the Jordan River runs between Lake Tiberias and the Dead Sea, and the Gulf of Aqaba; 2) the highland region (i.e., the mountainous terrain); 3) and the eastern region (i.e., the desert), which comprises more than 80 per cent of the country's area. The main topographical feature of Jordan is a dry plateau running from north to south. It rises steeply from the eastern shores of the Jordan River and the Dead Sea, reaching an average height of approximately 900 metres above sea level. The western region of the country is part of the Great Rift Valley, which includes the Jordan Valley, Dead Sea, Wadi Araba Desert and Gulf of Aqaba. In the north-western corner of the country, lies Lake Tiberias at an altitude of approximately 215 metres below sea level. The lowest point on earth is the Dead Sea, at approximately 400 metres below sea level. The eastern region is considered as part of the Syrian Desert, which extends towards the border with Saudi Arabia in the east and south of Jordan. The highest point is Jabal Ramm in the south, reaching 1,753 metres above sea level. Jordan is considered landlocked since it has no access to sea except for a short 30 km stretch of coast along the Gulf of Aqaba in the south.[3]
Climate	Jordan is characterized by long, hot, dry summers and short (November to March) but cool winters with snow on the western mountains. Its climate is influenced by the eastern Mediterranean and the Arabian Desert. The coldest month is January, with temperatures ranging between 5 and 10 °C and sometimes dropping to sub-zero for a few days. August is the hottest month with average temperatures between 20 and 35 °C. Daytime temperatures are usually high in Aqaba, the Jordan Valley and the eastern desert, especially during the summer season. Recently, daytime temperature exceeded 40 °C for a couple of days, which is an indication of climate change in the region. Summer winds are strong and hot, causing sandstorms in the desert and semi-desert areas during the spring season.[4]
Climate Change	The scarcity of water makes the management of water resources very complex from a political, technical, socio-economic and environmental perspective. Moreover, water resources in Jordan are extremely vulnerable to climate change. It is predicted that the annual precipitation may decrease, whereas maximum temperature, drought/dry days and evaporation may increase. It should be noted that in addition to the changing climate, the growing demand for fresh water in the country due to the sudden increase in population has also significantly contributed to reducing the per capita water availability.[5,6]
Rain Pattern	The annual precipitation and climatic conditions of the country do not support rainfed agriculture, except for limited regions in the northern and western highlands, where annual rainfall ranges between 250 and 450 mm. More than 80 per cent of the country territory, including the eastern and southern areas close to the border with Iraq and towards the border with Saudi Arabia, receives less than 100 mm of rainfall per year. The average annual rainfall volume in the country is approximately 1,000 million m³, of which only less than 4 per cent infiltrates to recharge the underground water. The rainfed agricultural zone is lying in areas where rainfall exceeds 250 mm, although significant production of cereals does occur in some areas where rainfall is between 200 and 250 mm. Most of the cultivated crops are irrigated by underground water and in the Jordan Valley by the King Abdullah Canal and King Talal Dam.[7]
Hydrology	Jordan is characterized by the lack of fresh water sources. However, in the past there were three rivers: the Jordan, the Zarqa and the Yarmouk. The saline Jordan River used to supply the Dead Sea, however, it was diverted by Israel in the early 1960s to supply in-land agricultural areas. The Zarqa River is dry since its main attributes were converted to supply fresh water for the cities of Amman and Zarqa and, moreover, it currently receives substantial municipal, industrial and agricultural effluent rendering it unsuitable for domestic or irrigation uses in the dry season. Only during flood periods does the water quality improve and the river finally supplies the King Talal Dam in the north-west of Amman, the country's largest surface water reservoir supplying water for irrigating the agricultural lowland in the Jordan Valley. The Yarmouk River originates from Syria and runs along the northern border and ends up at the Alwehdah Dam. During the winter, from November to March, rainfall in the mountains is concentrated down and forms streams in the valleys, called wadis, which remain dry or with a low flow rate during most of the year.[8]

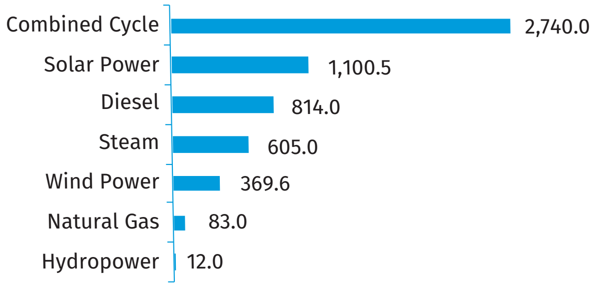
ELECTRICITY SECTOR OVERVIEW

Jordan is an energy importing country; approximately 93 per cent of its needs are supplied from abroad as natural gas, crude oil and refined products.[9] In 2019, the total energy demand was approximately 9.05 million toe, compared with 9.71 million toe in 2018 and 9.00 and 7.35 million toe in 2015 and 2010, respectively.[10,11,12] The primary energy consumption dropped by approximately 7 per cent in 2019 due to a slowdown of economic activities as a result of the general situation in the MENA region. In 2020, an additional drop in energy consumption due to the spread of COVID-19 and the suspension of most activities except the healthcare sector and some basic services. This situation is expected to continue during 2021–2023. The indigenous energy sources cover only a small fraction of the country's consumption, and in 2019 Jordan produced 0.136 million toe of natural gas and less than 0.0012 million toe of crude oil.[12] Thus, Jordan is heavily dependent on imported fossil fuels (oil products and natural gas) to fulfil its domestic energy needs in the transport, industrial, domestic heating and electricity sectors. The local energy demand is driven mainly by the electricity and transport sectors; in 2019, transportation and electricity generation accounted for approximately 35 and 30 per cent of total fuel consumption in the country, respectively.[12]

The maximum electricity demand in 2019 was 3,380 MW, while the contracted generation capacity was 4,332 MW, i.e., 128 per cent of the maximum demand. The total installed capacity was 5,728 MW at the end of 2019. The current mix is dominated by thermal power plants, of which 2,740 MW is from combined cycle plants, 814 MW from diesel units, 605 MW from steam turbines and 83 MW from gas turbines.[13] The renewable energy capacity consisted of 1,100 MW of solar photovoltaics (PV), 370 MW of wind power, 12 MW of hydropower and 3.5 MW of biogas capacity (Figure 1).[13] In 2010, almost all of the installed capacity in the country, including large industrial plants, was based on firing natural gas as a primary fuel and diesel oil or heavy fuel oil (HFO) as a secondary fuel.[13] As of 2021, a new oil shale direct combustion power plant in Attarat (470 MW) was under development by a consortium led by Esti Energia.[14] Additionally, a 13 MW wastewater treatment recovery plant is present and operating at the As-Samara wastewater treatment plant, producing 10 GWh annually.[15] This and other plants from individual power producers (IPPs) are not included in Figure 1 due to lack of comprehensive, centralized data.

The total generated electricity in 2019 reached 20,996 GWh, of which approximately 3,000 GWh (14.3 per cent) was from renewable energy sources dominated by solar PV (2,086 GWh) and wind power (892 GWh) (Figure 2). At the same time, electricity generation from hydropower was almost negligible: only 18.4 GWh. The dominant source of electricity generation was from firing fossil fuels, totalling 17,995 GWh.[13] The electricity imported from Egypt in 2019 totalled approximately 239 GWh, the electricity exported to the West Bank (city of Jericho) amounted to 91.7 GWh and a further 6.2 GWh was exported to the Iraqi border checkpoint.[12] Almost the entire population of Jordan (over 99.8 per cent) is served by and connected to the electrical grid, even the Syrian refugee camps in the north-east.[16]

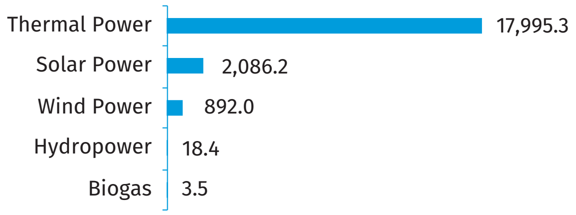
Figure 1. **Installed Electricity Capacity by Source in Jordan in 2019 (MW)**



Source: NEPCO[13]

Most of the sector's generation assets are owned and operated by local generation companies, IPPs and some industrial self-generators for on-site consumption. Most of the plants are located reasonably near to load centres, except the Aqaba thermal power plant, which is located on the Gulf of Aqaba to benefit from the sea water for cooling purposes, and renewable energy plants in the south of the country. All thermal in-land power plants are equipped with dry cooling systems due to the lack of surface water supplies in Jordan.

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



Source: NEPCO[13]

During the past two decades, there was a shift from steam turbines to higher efficiency combined cycle power plants fired with natural gas and to renewable energy plants. At the same time the capacity of open-cycle gas turbines, which have the lowest efficiency in the system, was reduced. Currently, there are approximately 1,500 MW of solar and wind power plants connected to the national and/or distribution grids, with a number of projects having been completed and having come online during 2016–2018. [12,17] Such an approach has been important for improving the efficiency of power generation in Jordan and for reducing the cost of unit of electricity produced. It is important to note that no energy storage systems, e.g., pumped storage, exist at present or are planned for the near future in the country.

A further 1,000 MW of solar and wind power capacity is in the pipeline and will be connected between 2021 and 2024.[17] These projects could substantially reduce the country's energy dependency and create significant fiscal benefits. The limited existing capacity of hydropower represents the current potential limited by lack of surface water resources.[18] However, there is a good chance for a few mini-scale plants to be installed on small dams and exits of wastewater treatment plants. Furthermore, real potential exists in exploiting the elevation difference between the Red and Dead Seas: seawater flowing from the Gulf of Aqaba into the Dead Sea through a canal system at predetermined rates can be used to produce electricity as well as potable water from seawater desalination plants. While this project is expected to help in establishing new economic activities, such as tourism and agriculture, it will also ensure the supply of large amounts of highly needed electricity and water as well as the replenishment of the Dead Sea by replacing the evaporated water. Feasibility reports have shown that within this project it is possible to build hydropower plants with a total capacity of 400–800 MW.[20] However, the required capital investment is extremely high due to the great length of the canal, i.e., approximately 200 km, and the necessary infrastructure.[19]

Electricity generation in Jordan has greatly increased over the past few decades in response to rapidly rising demand. In 2010, total electricity generation sold by the National Electric Power Company (NEPCO), the sector off-taker, to the country's distribution companies and wholesale consumers stood at approximately 14,258 GWh. Five years later, in 2015, it reached 18,911 GWh and jumped to 21,000 GWh in 2019.[13] The high growth rate of electricity consumption is resulting primarily from the country's population growth and increasing economic activity, including industrial production, commercial activities, tourism and construction activities as well as the increasing number of Syrian refugees.

The national grid is under the direct supervision of NEPCO. It consists of the main conventional and renewable energy power plants, 132 kV and 400 kV transmission networks and substations (400/132/33 kV and 132/33 kV with a total capacity of approximately 15,000 MVA). The system also includes three main interconnections: (i) 230 kV with Syria, (ii) 400 kV sub-marine cable with Egypt and (iii) a 33 kV connection with the West Bank (Jericho). In addition, there are three distribution grids, which consist of 33 kV, 11 kV and 400 V networks. Each of the electricity distribution companies owns and operates the grid in its distribution area: northern, central or southern region.

The Green Corridor project, which was completed in 2021, boosted the high-voltage (HV) grid's capacity by an additional 1,200 MW, to absorb loads generated by new renewable energy projects in the south. It consists of two new transmission lines (400 kV/150 km and 132 kV/51 km), upgrading three existing lines (132 kV/100 km) and including the construction of one new 400/132 kV, 1,200 MVA electricity substation.[13] This project will reinforce the network in the central Jordan desert area, where circumstances for renewable generation are most favourable. However, in May 2016, NEPCO suspended all wheeling applications to connect to the HV network.[20] The total losses (13.77 per cent) in the grid in 2019 were distributed as follows: 2.07, 2.18 and 12.35 per cent in generation, transmission and distribution, respectively.[11] Thus, major losses occurred in the distribution grids due to technical and increasing non-technical losses.

There is a growing interest among private investors in renewable energy projects, especially those oriented towards covering the demand of the commercial, industrial and service sectors, on wheeling basis and/or net-metering. Consequently, the Government of Jordan recently revised the regulatory framework to allow aggregation by groups of customers that also produce their own electricity. This is a positive move for small-scale plants that would otherwise face barriers to market entry due to their relatively small size compared to other grid-connected assets. However, there are some obstacles that need to be removed in order to attract the private sector to invest in renewable energy projects. The most important barriers are related to subsidies in the electricity tariffs (based on cross subsidization), unlimited authority given to electricity distribution companies regarding renewable energy systems and the imposed limitation on the capacity of wheeling projects of 1 MW.

The role of the regulator, Energy and Mineral Regulatory Commission (EMRC) is to monitor the tariff system and to ensure a balanced and acceptable cost of electricity for all sectors of the economy as well as for low-income households. Thus, the regulator should allow for tariff readjustment from time to time to account for the interests of all stakeholders, including the distribution companies, following certain performance indicators.

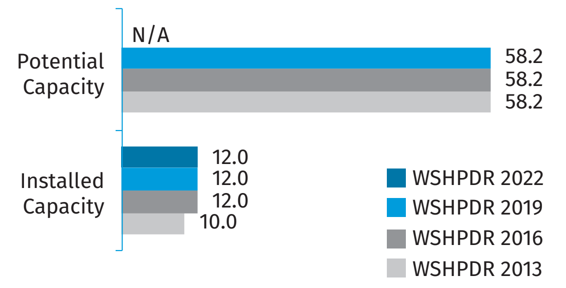
As a result of serious disruption of gas supply from Egypt during the 2010-2011 uprising, the Government of Jordan was forced to increase imports of petroleum products (diesel and HFO) to supply combined cycle and thermal power plants. Consequently, the public debt increased sharply and NEPCO was under pressure to adopt a cost-recovery strategy, which aimed to gradually increase the retail prices of electricity. From 2013, it was decided to increase the tariff by 15 per cent on a yearly basis until the end of 2016. However, the retail prices of electricity and water for the first two segments of residential consumers (1–160 and 161–300 kWh/month, respectively) are still subsidized. The prevailing electricity prices are considered among the highest in the region, as compared with neighbouring Arab countries (Table 1).

Table 1. **Retail Electricity Tariffs in Jordan in 2019**

Household electricity tariff segment	*Tariff (JOD/kWh (USD/kWh))*	*Domestic electricity tariff segment*	*Tariff (JOD/kWh (USD/kWh))*	*Commercial electricity tariff segment*	*Tariff (JOD/kWh (USD/kWh))*
First block: 1–160 kWh/month	0.033 (0.05)	First block: 1–160 kWh/month	0.042 (0.06)	First block: 1–2,000 kWh/month	0.120 (0.17)
Second block: 161–300 kWh/month	0.072 (0.10)	Second block: 161–300 kWh/month	0.092 (0.13)	Second block: > 2,000 kWh/month	0.175 (0.25)
Third block: 301–500 kWh/month	0.086 (0.12)	Third block: 301–500 kWh/month	0.109 (0.15)	Flat rate tariff for TV & broadcasting stations	0.173 (0.24)
Fourth block: 501–600 kWh/month	0.114 (0.16)	Fourth block: 501–600 kWh/month	0.145 (0.20)	Flat rate tariff for banking sector	0.285 (0.40)
Fifth block: 601–750 kWh/month	0.158 (0.22)	Fifth block: 601–750 kWh/month	0.169 (0.24)		
Sixth block: 751–1,000 kWh/month	0.188 (0.27)	Sixth block: 751–1,000 kWh/month	0.190 (0.27)		
Seventh block: > 1,000 kWh/month	0.265 (0.27)	Seventh block: > 1,000 kWh/month	0.256 (0.36)		

Source: NEPCO[13]

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



Source: NEPCO,[11] *WSHPDR 2013*,[21] *WSHPDR 2016*,[22] *WSHPDR 2019*[23]

Note: The absence of a potential capacity figure is due to a re-evaluation of the data provided in previous editions of the *WSHPDR*.

Table 2. **List of Operational Small Hydropower Plants in Jordan**

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Plant type*	*Turbine type*	*Operator*	*Launch year*
King Talal Dam	North-West Amman	5	50	Reservoir	Francis	Jordan Valley Authority	1984
Aqaba thermal power plant (non-operational)	Aqaba Gulf	7	35	Run-of-river	Francis	Central Electricity Power Generation Company	1988

Source: NEPCO[11]

SMALL HYDROPOWER SECTOR OVERVIEW

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

The existing hydropower sources in Jordan are limited since surface water resources, such as rivers and falls, are almost negligible. Currently there are two SHP plants: one on the King Talal Dam spanning the Zarqa River with an installed capacity of 5 MW and one at the Aqaba thermal power plant, where a hydropower turbine with a capacity of 7 MW utilizes the available head of returning cooling seawater (Table 2). However, the Aqaba thermal power plant has been kept on stand-by during the past years, thus, no power was generated by its SHP units. The total amount of electricity generated in 2019 by operational SHP units was 18.4 GWh, which accounts for approximately 0.1 per cent of the national electricity generation and 0.6 per cent of renewable energy generation.[11] There are no reliable data estimating the potential of SHP in the country. The installed capacity has not changed since the *World Small Hydropower Development Report (WSHPDR) 2019*, while the previously-cited potential capacity figure of 58.2 MW has been removed due to a reevaluation of the source data (Figure 3).

At present there are no official plans for the construction of new SHP projects in the country, although good potential exists in selected sites in the western mountains, i.e., close to the Jordan Rift Valley. In addition to the only irrigation dam, King Talal, currently utilized to generate electricity, there are other existing dams that are being utilized as storage reservoirs to meet water demand during the long dry summer season. Almost all of these sites are suitable to be upgraded for SHP and/or pumped-storage use since they are located in hilly areas in the western part of the country, where annual precipitation exceeds 400 mm and may reach 600 mm with snowstorms in some areas. Evaluating the case of a pumped-storage system for each site is very difficult at this stage, since the features and characteristics are site-specific depending on topography, average annual flow and other parameters. In addition, there is a number of other small dams under construction (Table 3). Thus, further work should be conducted to assess the potential and feasibility of such plants. However, these small dams may represent an opportunity for implementing SHP plants. The average exploitable potential of existing dams in the country is estimated to be between 30 and 50 MW.[24]

Table 3. **Storage Capacity of Proposed Small Dams in Jordan**

Name	*Location*	*Proposed storage capacity (10^6 m^3)*	*Status as of early 2020*
Maa'in	Madaba	1.0	Completed
Lajjun	Karak	1.0	Under construction
Dalaghah	Tafila	1.0	Completed
Shuthim	Tafila	1.0	Completed
Bin Hammad	Bin Hammad	5.0	Under construction
Wahidi	Maa'n	1.8	Under study
Wadi Karak	Karak	2.1	Updating studies
Bayer	Eastern desert	4.0	Completed
Jafer	Southern desert	0.5	Under construction
Rukban	North eastern desert	2.0	Completed
Khanasree	Mafraq	1.0	Under construction
Ghadaf	Central desert	0.5	Completed

Source: Ministry of Water and Irrigation[6]

The contribution of hydropower will remain constant in the coming years because of limited resources unless the Government decides to proceed with pumped-storage hydropower development. Unfortunately, there is a lack of awareness and knowledge concerning SHP and its benefits; not only among the public but also among concerned governmental agencies, non-governmental organizations and municipalities. It is believed that SHP could play a positive role in the country in the future, if a targeted programme is developed to assist farmers, local communities and other consumers to harness the benefits of SHP plants where their development is economically attractive. There have been no official studies on SHP development or potential and there are no plans to develop SHP in the country. However, an academic study with preliminary estimates was performed on theoretical potential of selected sites (Table 4).

Table 4. **Small Hydropower Plants Available for Development in Jordan**

Name	*Location*	*Potential capacity (MW)*	*Head (m)*	*Type of site (new/refurbishment)*	*Type of project*
Kufranjah	Ajlun	4.5		New	Reservoir
Bin Hammad	Bin Hammad	2.5		New	Reservoir
Bayer	Eastern desert	2.0		New	Reservoir
Wadi Karak	Karak	1.1		New	Reservoir
Rukban	North eastern desert	1.0		New	Reservoir

Source: Jaber[24]

Note: Data from 2012.

RENEWABLE ENERGY POLICY

Jordan is classified as one of the four most water scarce countries in the world. The National Agenda that sets the country's development vision until 2025 stresses that the development achievements are under threat due to water scarcity, which is expected to be aggravated by climate change. The Third National Communication to the United Nations Framework Convention on Climate Change (UNFCCC) predicted that by 2050 the country will witness rising temperatures, dropping rainfall, reduced ground cover, reduced water availability, heatwaves and more frequent dust storms.[5]

The share of Jordan in global greenhouse gas (GHG) emissions represents less than 0.06 per cent.[5] Although this is a very small contribution of the total, the per capita intensity of emissions in Jordan is considerably high: at approximately 3.0 ton of CO_2-eq for the period 2010–2020. This rate significantly exceeds that of most European countries and is almost similar to those of oil producing Arab countries. This implies that there is room for energy efficiency improvement and emissions reduction in all sectors by employing renewable energy and energy efficiency measures. The Government has developed a targeted programme aiming to reduce the national GHG emissions by 1.5 per cent by 2030 compared to a business-as-usual scenario level. However, the conditional outcome target set in the Intended Nationally Determined Contribution is aiming for a 12.5 per cent reduction of emissions by 2030. The two targets will be achieved based on implementing at least 70 projects, of which many are currently under execution by the relevant institutions and will be implemented under the guidance of the overarching national Climate Change Policy of the Hashemite Kingdom of Jordan 2013–2020.[6]

The National Energy Strategy Plan 2007–2020 is a nation-wide policy encompassing strategic objectives and measures for climate change mitigation and adaptation. It is considered the first of its kind in the Arab region and, in terms of sectoral coverage, in the Middle East. The plan demonstrates the self-commitment and ambition of the Government to make progress towards energy reduction in the wake of climate change, and ensure that commitments are followed through. The National Energy Strategy Plan 2007–2020 has been extended at the end of its term to 2030 to concurrently go in line with and serve as an overarching umbrella guiding and monitoring the implementation of the 70 project and 14 per cent GHGs emission reduction pathway of activities until 2030.

According to the Third National Communication, the GHG emissions, in the reference year 2014, reached 37 million tons of CO_2-eq, of which 73 per cent resulted from the energy and transport sectors.[6] The renewable energy projects completed between 2016 and 2018 are expected to contribute to a significant reduction in GHG emissions. The net anticipated accumulated reduction of GHG emissions over this period could exceed 16 million tons, with solar PV accounting for 45 per cent of total accumulated reduction, followed by wind power, at approximately 24 per cent, and direct applications of renewable energy by 28 per cent.[13] Additional renewable energy capacities to be completed by 2025 are expected to bring total emissions reduction up to 20 million tons.[6]

At present, there is no official policy targeting hydropower in general. The Red Sea–Dead Sea project is the largest potential hydropower development, but its future depends on the decisions made on the regional level. At present, there is no plan to develop SHP plants in Jordan and no indication of an official intention to go ahead in this direction, even from the regulation point of view. Subsidies for all electricity producers were removed by 2017 in order to help NEPCO cover its costs and no other renewable support schemes are currently available.[25]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Given the very limited water resources in the country, increased evaporation and decreased rainfall will have a dramatic effect on Jordan, eventually leading to reduced recharging of groundwater reserves. The long-term effect is expected to be very serious causing soil degradation, which could lead to desertification. Also, fewer agricultural crops would be available in the market due to the lack of suitable water for the agriculture sector.

The main obstacles facing the climate change adaptation measures in the water sector include the following:

- Climate change risks are not sufficiently taken into account within sectoral policies and investment frameworks;
- Existing climate information, knowledge and tools are not directly relevant for supporting adaptation decisions and actions;
- Limited national capacity to develop sectoral adaptation responses.[6]

Adaptation to the increased water scarcity and threats related to health, food security, productivity and human security induced by climate change is key to sustaining the development of Jordan. The Government has been the implementing partner in carrying out the activities of the United Nations Country Team (UNCT) joint programme on adaptation to climate change. One component of this joint programme has focused on the Zarqa River basin, including the development of a climate change adaptation programme for the basin and a pilot climate change intervention for groundwater protection for one local community in the basin.[26]

The main conclusion is that the limited local water resources are vulnerable to global warming, and adaptation actions and measures should be taken seriously at all levels. Thus, there is a real need to implement the policies and measures which were proposed in the Third National Communication. However, the implementation of recommended measures is subject to the condition of availability of needed funds from donors and international organizations.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Jordan has some potential for hydropower development, but to date only a very small portion of this potential has been harnessed as SHP plants. Jordan has very limited surface water resources and there is an urgent need to harvest water during the winter season. Therefore, dams can have double benefits: collecting water and electricity generation. Hydropower use can be linked to efforts contributing to sustainable development through flood control, irrigation, recreation activities as well as water supply for population needs. SHP development could offer a leading renewable energy alternative for meeting electricity demand in remote and mountainous parts of Jordan, with the advantages of SHP plants including the fact that they can either be standalone or in a hybrid combination with other renewable energy sources. Moreover, hydropower can contribute to reducing the dependence of Jordan on energy imports from neighbouring countries.

However, the Government has not paid any attention to the importance of SHP and no serious effort has been made to develop the most promising sites in the country. Thus, it is necessary to start developing a national strategy for promoting SHP in Jordan and removing existing barriers. The most important barriers are:

- The absence of a regulatory framework for SHP development;
- SHP is not included in the national plans, e.g., the updated national energy strategy;
- Lack of technical and specialized staff on operation and management of SHP units;
- Lack of public awareness and knowledge about SHP;
- Limited surface water resources;
- Lack of financial resources to construct dams and install the needed equipment.

However, some of the above barriers could be addressed by inviting the private sector to participate in the development of SHP projects on the basis of public-private partnerships as well as by inviting international donors to help develop the needed local expertise and capacity.

The only identified enabler for SHP development in Jordan is the potential of utilizing existing dam infrastructure to harness 30–50 MW of power. Furthermore, despite the limited water resources in the country, there are some springs, streams and outlets of wastewater treatment plants that can be used for SHP plants. Further investigations should be conducted to assess the techno-economic potential of such SHP installations.

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Lebanon

Karim Osseiran, Ministry of Energy and Water

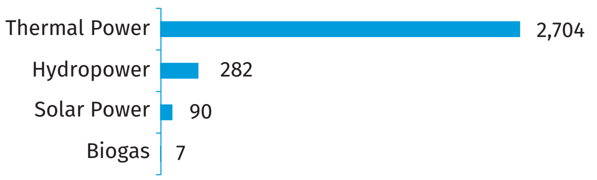
KEY FACTS

Population	6,825,442 (2020)[1]
Area	10,452 km^2 [2]
Topography	Lebanon consists of four physiographic regions: the coastal plain, the Mount Lebanon mountain range, the Beqaa Valley and the Anti-Lebanon mountain range in the eastern part of the country. Waterbodies account for 1.6 per cent of the country's surface area. The highest point in Lebanon is Qurnat as Sawda, at 3,088 metres above sea level, which lies in the north of the country and gradually slopes to the south before rising again to 2,695 metres as Mount Sannine.[3]
Climate	The climate is Mediterranean, with mild to cool, wet winters and hot, dry summers. The mountainous regions of the country experience heavy winter snows. The coldest month is January with average temperatures ranging between 5 °C and 10 °C. The hottest month is August at 18 °C to 38 °C.[4]
Climate Change	The ongoing effects of climate change on Lebanon include decreasing average precipitation and changes in the timing of seasons. An analysis of annual precipitation based on 80 years of observation showed a decreasing tendency since 1970.[5] According to an ensemble of climate projections, temperatures are expected to increase by 1.2 °C by 2046, by 1.7 °C by 2065 and by as much as 3.2 °C by 2100, relative to the 1986–2005 baseline period. An increase in the length of the dry summer season by an additional 6 dry days and as many as 43 additional days with a maximum daily temperature of above 35 °C annually are also expected by the end of the century.[6]
Rain Pattern	The rainy season is in the winter, with most of precipitation falling after December. Rainfall is generous but is concentrated over only a few days of the rainy season, falling in heavy cloudbursts. Annual precipitation averages 823 mm with great variations from one year to the next as well as among the regions: 600–1,000 mm in the coastal area, 900–1,700 mm on the western mountain range, 500–900 mm on the eastern mountain range and 200–900 mm in the Beqaa Valley. Much of this precipitation, however, is lost to evaporation, neighbouring countries and the Mediterranean Sea, while a relatively small percentage remains available as underground and surface water. Approximately once in every 15 years a light powdering of snow falls as far south as Beirut.[3,5]
Hydrology	The Lebanese territory is drained by seasonal torrents and 17 main rivers, three of which — the Orontes (Assi), Nahr El Kebir and Nahr El Hasbnani — are transboundary rivers. The Litani is the largest river in Lebanon, draining a basin of 2,290 km^2 and developing its course over a total length of 170 km. There are six medium-sized rivers of 30–60 km in length with basin areas ranging between 300 km^2 and 600 km^2 and eight smaller rivers of 25–40 km in length with basin areas ranging between 100 km^2 and 300 km^2.[3,7]

ELECTRICITY SECTOR OVERVIEW

The installed capacity of Lebanon amounted to 3,083 MW at the end of 2020, including 2,704 MW (88 per cent) provided by conventional thermal power including temporary barges, 282 MW (9 per cent) provided by hydropower, 90 MW (3 per cent) provided by solar power and 7 MW (less than 1 per cent) provided by landfill gas (Figure 1).[8,9,10,11] However, reported available effective capacity was significantly lower, as it has been for many years. In 2019, available capacity and peak demand were estimated at approximately 2,449 MW and 3,669 MW, respectively.[8] Following the suspension of operation of the two temporary barges in October 2021, available capacity was reduced by a further 374 MW.[8,12]

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



Source: MoEW,[8] Government of Lebanon & UN,[9] IRENA,[10] Tsagas[11]

As a result of the gap between supply and demand, self-generation remains significant in Lebanon. A 2020 World Bank study estimated the installed capacity of diesel generators in Lebanon in 2018 at approximately 1,390 MW. The total commercial generator market size was estimated at USD 1.1 billion.[13]

Total electricity generation in Lebanon by grid-connected power plants equalled approximately 14,501 GWh in 2017, with thermal power accounting for approximately 14,036 GWh (almost 97 per cent) of the total, hydropower providing 424 GWh (3 per cent) and biogas providing 41 GWh (less than 1 per cent).[14] The share of hydropower generation typically fluctuates between 2 per cent and 4 per cent depending on yearly precipitation.[14] Meanwhile, total annual electricity demand in 2017 reached approximately 21 TWh, with most of the difference having been covered by off-grid diesel generators. The share of the supply deficit relative to demand increased from 22 per cent in 2006 to 37 per cent in 2018 and is expected to reach 56 per cent by 2026.[13]

Approximately one third of the energy produced by grid-connected power plants was not billed in 2017, with 20 per cent of generation lost to theft and billing errors, and technical losses accounting for another 14 per cent.[15] Access to electricity in Lebanon was 100 per cent as of 2019.[16] However, starting from 2011, the Syrian crisis has caused an influx of refugees into Lebanon. As indicated by a 2017 United Nations Development Programme (UNDP) assessment, this has led to a surge in electricity demand and surpassed most efforts made by the Government to improve supply, leaving the country with a higher energy deficit than in 2012. The assessment revealed that the 1.5 million displaced Syrian refugees present in the country at the time required an additional 450 MW to 480 MW of power supply, and that the percentage of displaced Syrians with non-metered connections to the grid varied from 36 per cent in the north of Lebanon to 82 per cent in Beirut and Mount Lebanon, with an average of 45 per cent across the country, with the cost of these factors to the national economy of Lebanon estimated at over USD 330 million per year.[17]

The most important player in the electricity sector of Lebanon is the state-owned company Electricité du Liban (EDL), which was granted exclusive authority in the generation, transmission and distribution sectors by Decree No. 16878 of 1964 and Decree No. 4517 of 1972.[18] The company operates at a loss, with an annual deficit of between USD 1.2 billion and USD 1.8 billion. It is hobbled by a lack of investment, rising cost of fuel, aging power plants, high technical and commercial losses in transmission and distribution, an inefficient tariff structure, electricity tariffs frozen at a level below the average cost of production and deteriorating financial, administrative, technical and human resources as well as convoluted legal and organizational frameworks.[8,19]

Following the endorsement of the Electricity Policy Paper by the Government of Lebanon in 2010, several initiatives have been launched to address the insufficient generation capacity. In 2012, the Government, represented by the Ministry of Energy and Water (MoEW), entered into a contract agreement with the Turkish company Karadeniz for renting 270 MW of reciprocating engines mounted on floating barges. The barges are based in Jiyeh and Zouk municipalities near the sites of existing thermal power plants. In 2016 the barges rental contract was extended for a two-year period until late 2018 and the capacity of the Jiyeh-based barge was increased by 110 MW. Subsequently, the contract was further extended until the end of September 2021. Following the expiration of this contact, Karadeniz stopped supplying power to the national grid on 1 October 2021, with no clear prospects for a further contract renewal and resumption of supply.[12] Furthermore, in late 2016 two reciprocating engine power plants were synchronized on the sites of the existing Zouk and Jiyeh thermal power plants, providing the sites with an additional 194 MW and 78.2 MW, respectively. Finally, as part of an operation and maintenance contract, EDL implemented upgrade packages sequentially at the Zahrani and Deir Amar thermal power plants. The upgrade was completed by the end of summer 2013 and provided a total additional capacity of at least 63 MW, in addition to enhancements in efficiency and lifetime extensions.[9]

In 2010, Law 462 introduced a legal framework for the privatization, liberalization and unbundling of the electricity sector, but has not yet been applied. In 2014, Law 462 was partially superseded by Law 288, which established that pending the implementation of Law 462, independent power producers (IPPs) could be licensed by the Council of Ministers (COM) upon joint recommendations from MoEW and the Ministry of Finance during the period between April 2014 and April 2016. Furthermore, in October 2015 the Parliament of Lebanon approved Law 54, extending the duration of Law 288 until April 2018. Finally, in May 2018 the Lebanese Council of Ministers approved a draft law calling for the extension of Law 54 for a further two-year period.[20]

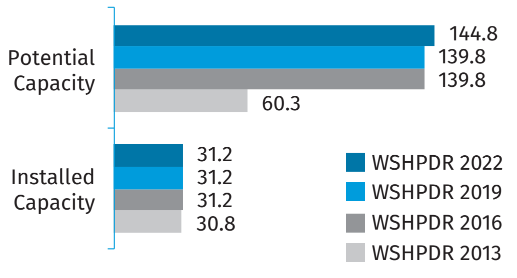
Based on the application of Law 288 and Law 54, in 2018 the Government of Lebanon signed a power purchase agreement (PPA) with a planned wind power project of 226 MW of total installed capacity. This was the first PPA signed in Lebanon for electricity produced from renewable energy sources.[10] In April 2018, the MoEW published a call for expressions of interest from private investors and companies for the construction and operation of hydropower plants, with a deadline in mid-June 2018. The goal was to incentivize the participation of the private sector in hydropower construction and financing through 20-year PPAs.[20] The implementation of the new project initiatives was however stalled by an economic crisis and a period of political instability developing in Lebanon since 2019. The impact of the COVID-19 pandemic and the Beirut Port explosion in August 2020 further aggravated the economic crisis, forcing the resignation of the Government and leading to the default of Lebanon on its sovereign debt for the first time in history. All of these factors made new project financing impossible due to the absence of public funding and the inability to attract private funding due to unprecedented challenges to the bankability of potential projects.

Electricity provided by EDL is heavily subsidized, with tariffs for end users far below the cost of production. In 2019, electricity tariffs for end users averaged 0.095 USD/kWh, while the cost of generation ranged between 0.160—0.250 USD/kWh.[21] However, as electricity supply from the grid is extremely limited, most electricity users are connected to diesel generators operated by private owners, and pay considerably more. The MoEW has been attempting to control electricity prices set by metered generator owners with only limited success, as most generator connections remain unmetered. The price for electricity from metered generators set by MoEW for December 2021 was 7,104 LBP/kWh (approximately 0.259 USD/kWh, according to unofficial exchange rates).[22,23] The price of an unmetered generator connection could reach up to 375 USD per month in 2021, with stable electricity supply still contingent on the availability of fuel.[24]

SMALL HYDROPOWER SECTOR OVERVIEW

The definition of small hydropower (SHP) in Lebanon is up to 10 MW. As of 2021, the country had seven SHP plants with a total installed capacity of 31.2 MW, with one plant (Jeita) being out of service (Table 2).[25,26] SHP potential capacity is estimated at 144.8 MW, indicating that approximately 22 per cent has been developed.[7,27] Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, potential capacity has increased by approximately 3 per cent due to a reinterpretation of available data, while installed capacity has remained the same (Figure 2).[28]

Figure 2. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2021 in Lebanon (MW)**



Source: SOGREAH & MoEW,[7] Osseiran,[25] MoEW,[26] UNDP & CEDRO,[27] *WSHPDR 2019*,[28] *WSHPDR 2013*,[29] *WSHPDR 2016*[30]

Table 2. **List of Installed Small Hydropower Plants in Lebanon**

Name	*Location*	*Capacity (MW)*	*Operator*	*Launch Year*
Blaouza	Kadisha Valley	3 x 2.80 MW	La Kadisha - Société Anonyme D'électricité Du Liban Nord S.A.L. (EDL Owned)	1961
Mar Licha	Kadisha Valley	3 x 1.04 MW	La Kadisha - Société Anonyme D'électricité Du Liban Nord S.A.L. (EDL Owned)	1957
Fitri	Nahr Ibrahim River	3 x 1.66 MW	Société Phoeniciene Des Forces De Nahr Ibrahim Des Eaux Et Electricité	1951
Abu-Ali	Kadisha Valley	2 x 2.72 MW + 1 x 2.04 MW	La Kadisha - Société Anonyme D'électricité Du Liban Nord S.A.L. (EDL Owned)	1932
Al Bared 2	Nahr Al Bared River	1 x 1.20 MW + 1 x 2.50 MW	Al Bared Concession	1936
Bechare	Kadisha Valley	2 x 0.82 MW	La Kadisha - Société Anonyme D'électricité Du Liban Nord S.A.L. (EDL Owned)	1924
Jeita	Nahr Al Kalb River	1 x 0.31 MW + 2 x 0.80 MW	Water Authority for Mount Lebanon	N/A
Total		**31.24**		

Source: IRENA,[10] Osseiran,[25] MoEW[26]

In 2012, MoEW, in collaboration with the consultancy firm Sogreah-Artelia, prepared a master plan study of the country's hydropower potential along the main river streams. The study identified 32 new sites that have a potential hydropower capacity of 263 MW (1,271 GWh/year) in run-of-river projects and 368 MW (1,363 GWh/year) in peak projects (i.e., with reservoir infrastructure). The Sogreah-Artelia study identified three levels of new hydropower sites. Approximately 125 MW of the identified potential capacity from exceptionally favourable locations with low environmental impact and relatively low levelized costs. An additional 100 MW is also available and viable, although in conditions relatively less favourable than those of the first level, while a final 25 MW exists under even less favourable conditions. In all three cases, special attention must be attributed to the environmental impacts of the projects. All three levels (except for one site) have levelized costs lower than the current average EDL generation costs (which is at least 0.17 USD/kWh).[7,31]

Of the identified 32 sites, 23 are up to 10 MW, with a total potential capacity of 108.6 MW and an expected total annual generation of 533 GWh.[7] Some of the planned SHP plants may be developed within the framework of the expression of interest launched by MoEW in April 2018. Micro- and mini-hydropower plants are likely to become relatively more important in Lebanon if the country is to preserve and increase its hydropower resources. Additionally, a United Nations Development Programme Country Entrepreneurship for Distributed Renewables Opportunities (UNDP-CEDRO) study from 2013 focused on a selection of potential sites where hydropower could be utilized, namely cooling systems of nearshore power plants, irrigation channels, water networks and sewage networks. This study identified 13 pilot sites with a capacity of approximately 5 MW. However, a bigger potential for non-river SHP development remains to be identified and tapped into.[27,31]

The first hydropower plant in Lebanon was built in Bécharé in 1924, under the French mandate. Lebanon experienced rapid development of hydropower plants starting from the 1920s and until the beginning of the Lebanese Civil War in mid-1970s. At its peak of development in 1976, hydropower in Lebanon provided approximately 70 per cent of annual electricity production.[32] In 2016, MoEW, with the technical assistance of the World Bank, conducted a study aiming to analyze the current legal, regulatory and administrative status of the development and rehabilitation of hydropower plants in Lebanon, to identify potential barriers and delineate further steps towards making hydropower a considerable part of the national energy mix. The study noted that although the hydropower sector has historically played a significant role in the electrification of Lebanon, today it can hardly be a driver of the country's energy sector development or the mainstay of electricity generation. The key factor is the current demand for electricity exceeding the available hydropower potential in the country by a factor of 15. Nevertheless, the hydropower sector can play an important role in the initiation of an electricity market reform, as significant experience in this field already exists. Key recommendations of the MoEW study included the following:

- Place emphasis on adopting an overall strategy aiming at raising the significance of hydropower and undertaking initiatives on legal, administrative, policy and financial issues;
- Establish a Hydropower Development Unit to enhance the capacity for the development, management and monitoring of hydropower projects;
- Establish a Hydro Account for transactions related to potential agreements in order to minimize the exposure of the hydropower sector to the liabilities of the overall energy market, reduce financial uncertainties and increase the prospects for a sustainable procedure of awarding future hydropower agreements;
- Promulgate the required legal and regulatory amendments and ministerial decisions in the areas of the Water Code, hydropower agreements, establishment of the Hydro Account and public private partnership/ independent power producers (PPP/IPPs), in order to introduce a modernized tendering procedure, a sustainable remuneration/ financing mechanism and the establishment of a proper regime for attracting investments;
- Enhance private sector participation both at the technical (i.e., engineering and environmental studies) as well as at the investment and financing levels, and consider and promote appropriate joint-venture and PPP schemes, so long as fair competition is not distorted;
- Implement an Action Plan aiming to more than double the total capacity of hydropower plants, from 282 MW as of the time of writing of this chapter to more than 600 MW in 2026.[25]

RENEWABLE ENERGY POLICY

In addition to existing hydropower capacity and developed hydropower potential, Lebanon has significant wind power potential, especially in the north. A national wind atlas has been produced, providing indicative estimates as well as aggregating the total wind power potential in the country. Furthermore, the country possesses abundant solar power resources, with an average annual insolation of 1,800–2,000 kWh/m^2.[5]

At the United Nations Framework Convention on Climate Change (UNFCCC) COP15 meeting in Copenhagen in 2009, the Lebanese Government made a pledge to increase the share of renewable energy in the country's energy mix to 12 per cent.[5] This political commitment was a major milestone of the Policy Paper for the Electricity Sector. Adopted as the national strategy for the electricity sector, the policy paper clarified the national renewable energy target as being 12 per cent of the total electricity and heat energy supply by 2020. In November 2016, the Lebanese Center for Energy Conservation launched the National Renewable Energy Action Plan (NREAP 2016–2020). To reach the overall target of 12 per cent, the NREAP set the following targets for renewable energy sources in the total energy demand for electricity generation and heating in 2020: 2.1 per cent for wind power, 4.2 per cent for solar power (including solar photovoltaics (PV), concentrated solar power (CSP) and solar water heaters), 3.2 per cent from hydropower and 2.5 per cent from biomass.[31] Although the overall target for a 12 per cent renewable energy share by 2020 was not achieved, the share of RES in electricity generation is likely to be growing rapidly, both due to the widespread adoption of solar panels as well as a decline in generation from thermal power due to a lack of fuel.[24,32]

In 2016, the Government also announced the Second National Energy Efficiency Action Plan (NEEAP 2016–2020), a strategic document paving the way for meeting the overall national objective of 12 per cent of renewable energy by 2020. The NEEAP 2016–2020 came as a continuation of the NEEAP 2011–2015 and covers 14 independent but correlated activities in the energy efficiency and renewable energy sectors. The following progress towards the established targets was recorded during the period 2011-2015:

- Banning the import of incandescent lamps to Lebanon – 45 per cent completed;
- Adoption of Energy Conservation Law and institutionalization of LCEC as the energy agency – 40 per cent completed;
- Promotion of decentralized power generation by PV and wind applications – 30 per cent completed;
- Solar water heaters for buildings and institutions – 53 per cent completed;
- Design and implementation of a National Strategy for Efficient and Economic Public Street Lighting – 60 per cent completed;
- Electricity generation from wind power – 23 per cent completed;

- Electricity generation from solar energy – 42 per cent completed;
- Hydropower for electricity generation – 34 per cent completed;
- Geothermal, waste to energy, and other technologies – 30 per cent completed;
- Building code for Lebanon – 0 per cent completed;
- Financing mechanisms and incentives – 80 per cent completed;
- Awareness and capacity building – 69 per cent completed;
- Paving the way for energy audit and ESCO business – 20 per cent completed;
- Promotion of energy efficient equipment – 8 per cent completed.[33]

The commitment of Lebanon to scaling up the use of renewable energy technologies is strengthened by the ongoing updates to its renewable energy targets. A new target aiming to meet 30 per cent of total primary energy consumption (electricity and heating demand) from renewable sources by 2030 was introduced in 2018 and formed the basis of a first update to the electricity reform paper in March 2019. In 2020, a Renewables Readiness Assessment and REmap analysis study was carried out by the International Renewable Energy Agency (IRENA) in collaboration with MoEW and the Lebanese Center for Energy Conservation (LCEC). The study provided an in-depth assessment of the policy, regulatory, financial and capacity challenges that must be overcome to achieve the targets set out for 2030. Based on IRENA's REmap analysis, Lebanon has the potential to supply 30 per cent of its electricity mix from renewable sources by 2030. With renewable power, heat and fuels all factored in, renewable energy could provide approximately 10 per cent of the country's total final energy supply in 2030, up from less than 1 per cent in 2014. The successful realization of this outcome would require making major adjustments to policy, regulatory, technology, infrastructure and financing mechanisms. A significant conclusion of the study was that the framework currently in place does not fully account for the rapid economic and technological changes taking place at the national and regional levels, and several key challenges would need to be addressed to further overcome the ongoing energy crisis.

The study proposed the following recommendations in order to enable Lebanon to meet — and, in due course, exceed — the targets set in the NREAP:

- Implement a stable and integrated regulatory framework for renewable energy development, taking into account the obstacles posed to private sector investment by several existing laws of conflicting dispositions;
- Adopt new measures for small-scale renewable energy development, including PPAs allowing developers, especially in the solar PV sector, to sell electricity to specific consumers through peer-to-peer arrangements including ones relying on blockchain technology;
- Provide additional financial incentives for solar water heaters through international grant-based financing;
- Adopt technology-specific targets for renewable energy to meet the overall goal of 30 per cent share of renewable sources by 2030, including 1,000 MW of wind power, 601 MW of hydropower, 2,500 MW of centralized solar PV power, 500 MW of decentralized solar PV power and 13 MW of biogas, and for these targets to be complemented by improvements in energy efficiency;
- Increase tariffs and reduce electricity subsidies, which may encourage public and private investments in renewable energy projects and allow for the proliferation of renewable energy technologies through small- and medium-scale deployment;
- Reinforce the electricity grid to reduce technical and non-technical losses and improve system stability;
- Weak risk allocation due to political instability, grid, resource and off-taker risk, as well as burdensome administrative schemes must all be addressed and suitable risk mitigation instruments introduced to allow international financing institutions to move from issuing concessionary loans to providing blended finance;
- Improve the transparency of land ownership across the country, particularly in regions with high wind and solar power development potential such as the Bekaa Valley, Akkar and Hermel.[10]

COST OF SMALL HYDROPOWER DEVELOPMENT

The Sogreah-Artelia study commissioned in 2012 identified 23 potential SHP sites with total project cost estimates ranging from USD 1 million to USD 42.6 million USD and costs per kilowatt of installed capacity ranging from approximately 1,300 USD/kW to 5,100 USD/kW. Construction of the plant itself, including the valves, turbine, alternators and transformers, was estimated to account for approximately 39 per cent of the total cost on average. A considerable portion of the total cost, on average approximately 27 per cent, was estimated to go towards tunnelling work.[7]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

Financing for renewable energy projects, including SHP, is available in Lebanon from several sources. These include the National Energy Efficiency and Renewable Energy Action (NEEREA) financing mechanism made available by the Central Bank of Lebanon as well as loans from the Green Economy Financing Facility (GEFF) and the Lebanon Energy Efficiency and Renewable Energy Finance Facility (LEEREFF). IRENA has provided support for green finance in Lebanon by developing country-specific contract templates in collaboration with the Terawatt Initiative. Additionally, an online matchmaking service enabling developers, lenders and investors to identify providers of risk mitigation instruments (RMIs) is available through IRENA's Climate Investment Platform (CIP).[10]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Results from the Met Office Hadley Centre's PRECIS regional climate model for Lebanon indicate a reduction of rainfall of 10–20 per cent by 2040 and of 25–45 per cent by 2090, as well as an increase of 15–25 days in the number of consecutive annual dry days. These changes are expected to lead to increased hydrological stress, which, coupled with increased demand for indoor cooling due to rising temperatures, is expected to put additional pressure on the hydropower sector. Reductions in annual generation from hydropower in Lebanon are expected to amount to approximately 150 GWh by 2040 and 540 GWh by 2090, based on 2015 estimates.[6,34]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The development of SHP in Lebanon is hindered by a number of factors, as outlined below:

- Most of the existing hydropower concessions of Bared, Kadisha, Nahr Ibrahim and Litani are close to expiration (by 2030) and are selling the electrical energy produced to EDL at low tariffs;
- The current legal framework gives the exclusive rights to water resources to the General Directorate of Hydraulic and Electric Resources at MoEW, while electricity production is given to EDL;
- There are multiple stakeholders involved in the hydropower sector, which leads to excessive administrative burdens and complicates decision making;
- The geology of Lebanon is such that high costs of dam construction and limited water resources make the development of hydropower facilities unfeasible in many cases;
- While non-powered water infrastructure is available in different parts of the country, introducing a hydropower component to a dam, irrigation channel or other facility is difficult and sometimes not feasible at all if not done in the design stage;
- Water is becoming increasingly scarce, whereas demand for potable water and irrigation are increasing;
- The ongoing multifaceted crisis in the country makes access to financing difficult.

The enablers for SHP development in Lebanon include:

- The experience of Lebanon in hydropower development;
- Considerable untapped SHP potential;
- Availability of detailed studies of specific potential SHP sites.

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Saudi Arabia

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KEY FACTS

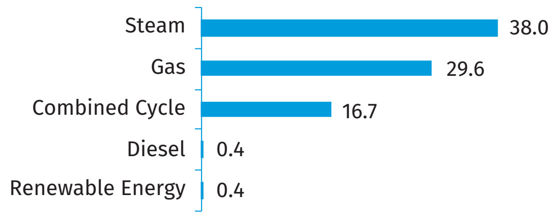
Population	34,813,867 (2020)[1]
Area	2,149,690 km^2 [2]
Topography	The Kingdom of Saudi Arabia represents approximately 80 per cent of the territory of the Arabian Peninsula. The country has a 2,410 kilometre-long sea coast, of which 1,760 kilometres stretch along the Red Sea and 650 kilometres represent the eastern coast of the Arabian Gulf. Forest lands in Saudi Arabia cover 2.7 million hectares and rangelands extend over 171 million hectares. The country is mostly a sandy desert, with the lowest point in the Arabian Gulf at 0 metres and the highest point at Jabal Sawda at 3,133 metres.[3,4]
Climate	Saudi Arabia has a harsh, dry desert climate with great temperature extremes. The temperature distribution across the country is controlled mainly by altitude and, to a lesser extent, by proximity to the sea. Typical daytime temperatures from May to September are between 38 °C and 43 °C across most of the country, in comparison to 30–32 °C at 2,100 metres above sea level at Khamis Mushait. However, there is usually a sharp drop of temperature at night. The annual mean temperatures range from 30 °C to 31 °C in low-lying Dhahran, Makkah and Jizan and from 22 °C to 25 °C in Riyadh and Tabuk in the north-west and stand at 20 °C in Khamis Mushait in the south-west.[2,4,5,6]
Climate Change	Between 1960 and 2010, the observed warming trend has amounted to approximately 0.41 °C and 0.16 °C per decade for summer and winter temperatures, respectively. An extreme heatwave has been observed in Jeddah and other parts of the country in 2010, with temperatures reaching 52 °C.[6]
Rain Pattern	Most rainfall in Saudi Arabia comes in the winter and spring. However, rainfall is unreliable and annual average totals are approximately 100 mm and less in inland parts of the country. For example, in Tabuk in the north-west, average annual rainfall amounts to 35 mm. The most abundant precipitation falls in the mountainous region in the far south-west of the country. In this area, rainfall typically occurs in the spring and summer, raising annual totals to 199 mm in Khamis Mushait and 141 mm in Jizan on the adjacent coastline. In the northern half of the country, rainfall occurs mainly between November and April, caused by weather systems moving eastwards from the Mediterranean or Northern Africa.[6,7,8]
Hydrology	Saudi Arabia is a desert country with no permanent rivers or lakes.

ELECTRICITY SECTOR OVERVIEW

The total installed capacity of Saudi Arabia was approximately 85.2 GW in 2019, with the overwhelming majority coming from non-renewable thermal power. Steam turbine plants provided 38.0 GW (45 per cent) of the total, gas turbine plants provided 29.6 GW (35 per cent), combined-cycle plants provided 16.7 GW (20 per cent), diesel generators provided 0.4 GW (less than 1 per cent) and renewable energy sources (RES), primarily solar power, likewise provided 0.4 GW (less than 1 per cent) (Figure 1).[9]

Saudi Arabia is divided into five geographical regions: Eastern, Central, Western, Southern, and Northern. In the Eastern, Central and Western regions, there is an interconnected grid that feeds the major load centres of each region. In these three geographical regions, isolated systems represent only a small percentage of the total load. In the Southern region, there are four autonomous systems that are not presently interconnected with each other. There is a plan to link these four autonomous systems into a unified grid for the Southern region's major load centres. In the Northern region, there are a number of isolated systems.

Figure 1. **Installed Electricity Capacity by Source in Saudi Arabia in 2019 (GW)**

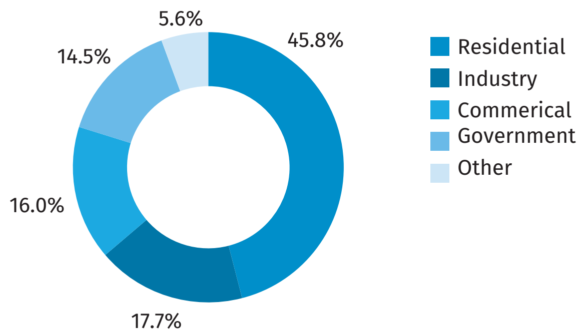


Source: ECRA[9]

The Eastern Operating Area (EOA) is responsible for the largest share of electricity generation in the country. EOA is connected to the Central Operating Area (COA) by a 230 kV double-circuit line and two 380 kV double-circuit lines.

Total electricity generation in Saudi Arabia was 340.9 TWh in 2020, decreasing by approximately 1 per cent from 343.7 TWh generated in 2019. Generation from RES was limited, with solar power contributing approximately 1 TWh in 2020.[10] The electrification rate in Saudi Arabia was 100 per cent as of 2019.[11] Electricity consumption was approximately 279.7 TWh in 2019, declining from 289.9 TWh the previous year. In 2019, the residential sector accounted for approximately 128.1 TWh (nearly 46 per cent) of total consumption, the industrial sector accounted for 49.4 TWh (18 per cent), the commercial sector for 46.0 TWh (16 per cent), the government sector for 40.5 TWh (15 per cent) and other sectors for 15.6 TWh (6 per cent) (Figure 2). Peak electricity demand in 2019 reached 62,076 MW.[9]

Figure 2. **Electricity Consumption by Sector in Saudi Arabia in 2019 (%)**



Source: ECRA[9]

Electricity consumption in Saudi Arabia was fairly stable between 2015 and 2018 and declined slightly in 2019.[9] However, climate has a significant impact on electricity consumption in the country, as air conditioning accounts for 70 per cent of all electricity use. This contributes to market seasonality, with summer peak demand almost double that of the winter average. It is estimated that total installed capacity in Saudi Arabia must rise to 120 GW by 2032 in order to meet the projected growth in electricity consumption. Additional proposals include merging the electricity grids of Saudi Arabia and several other Gulf States and linking them to the electricity grids of the European Union (EU), Egypt and Turkey. A power sharing arrangement with the EU is also proposed, providing excess power to the EU during the winter season, while receiving additional power during the summer peak demand period in Saudi Arabia itself.[12]

The Saudi Electricity Company (SEC) is the largest electricity producer in the country, operating 53 GW of installed capacity as of 2020 and being responsible for approximately half of total generation. In 2020, SEC connected an additional 776 MW of generating capacity to the national grid. The company has set the following objectives, to be completed by 2023:

- Increasing generating capacity by an additional 8,203 MW;
- Adding 5,402 kilometres of transmission lines and 86 transmission substations;
- Adding 126,388 kilometres of lines to the distribution network;
- Delivering electricity to an additional 1 million customers to account for population growth, reaching a total of 11 million customers.[13]

Electricity tariffs in Saudi Arabia were last modified in 2017 by Council of Ministers Resolution No.166 and have been in effect as of 1 January 2018. Tariffs include a consumption tariff that varies by consumer category as well as a monthly connection charge based on breaker capacity. Connection charges range between SAR 10 and SAR 30 (USD 2.67–8.00). Consumption tariffs are provided in Table 1.[14]

Table 1. **Electricity Consumption Tariffs in Saudi Arabia**

Consumption category (kWh)	*Consumer category tariff (SAR/kWh (USD/kWh))*					
	Residential	*Commercial*	*Agricultural and charities*	*Governmental*	*Industrial*	*Private educational and medical facilities*
1–6,000	0.18 (0.049)	0.20 (0.054)	0.16 (0.043)	0.32 (0.086)	0.18 (0.049)	0.18 (0.049)
Over 6,000	0.30 (0.081)	0.30 (0.081)	0.20 (0.054)			

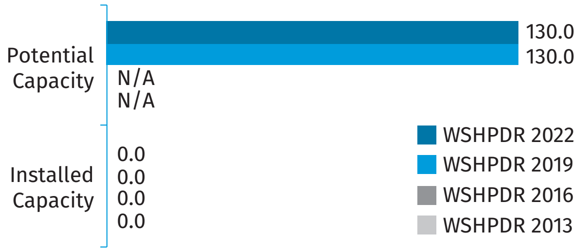
Source: SEC[14]

SMALL HYDROPOWER SECTOR OVERVIEW

Saudi Arabia has no installed hydropower facilities of any kind and no formal definition of small hydropower (SHP). However, dams have been constructed to make use of the little rainfall to recharge subterranean water supplies and control flooding. There are more than 200 dams in the country, with a cumulative reservoir capacity of 774 million m³. The King Fahd Dam is the largest in the country by reservoir volume, with a storage capacity of 325 million m³. At the same time, the effectiveness of dams in Saudi Arabia in containing rainfall water is greatly undermined by the excessive evaporation and sedimentation.[12,15]

Potential hydropower capacity from the Wadi Baish Dam and the King Fahd Dam has been estimated at between 9 MW and 10 MW each, from the Wadi Hali Dam between at 8–9 MW, from the Wadi Rabigh Dam and the Al-Lith Dam at 7–8 MW each and from the Al-Madeeq Dam at 5–6 MW. Hence, the total estimated potential capacity that could be installed at all six dams is between 45 MW and 51 MW. Assuming 50 per cent operation at peak installation, these plants could generate electricity at an average of 210 GWh per year. In addition to the six dams mentioned above, there were also 51 other smaller dams with estimated total potential capacity of 82 MW. Assuming 50 per cent operation at peak installation, the plants would generate electricity at an average of 360 GWh per year. As all proposed projects would have an installed capacity of under 10 MW, the total SHP potential capacity of the country can be estimated at approximately 130 MW (570 GWh per year) (Figure 3).[16]

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



Source: Obaid,[16] *WSHPDR 2013*,[17] *WSHPDR 2016*,[18] *WSHPDR 2019*[19]

RENEWABLE ENERGY POLICY

Saudi Arabia has the world's largest proven oil reserves, the world's fourth largest proven gas reserves and is the world's 20th largest producer and consumer of electricity. Saudi Arabia makes negligible use of RES and almost all its electricity is produced from the combustion of fossil fuels. At the same time, Saudi Arabia has considerable RES potential, mainly in the form of solar energy. Unlike other countries exhibiting high population density, the country's vast desert can host large solar installations and its huge deposits of clear sand can be used to manufacture silicon photovoltaic (PV) cells. The Government of Saudi Arabia is interested in increasing generation from RES in order to meet the domestic power needs, free up oil for export and drive natural gas consumption towards sectors with higher added value such as petrochemicals.

In 2012, Saudi Arabia launched an ambitious USD 109 billion plan to install 41 GW of solar power (including 25 GW of concentrated solar power and 16 GW of solar PV projects), 9 GW of wind power, 3 MW of waste-to-energy projects and 1 MW of geothermal power by 2032, corresponding to 30 per cent of planned electricity generation capacity for that year. The RES sector is expected to bring important returns, in particular in terms of employment. In addition to the diversification of the domestic energy mix, RES is expected to contribute to the reduction of emissions growth (NOx, SOx and CO2), effluents and water usage, as well as provide an alternative means of serving remote areas in a more economic and environmentally sustainable manner. However, RES development has been slow, with less than 1 per cent of the country's installed capacity provided by RES as of 2019.[9]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The two key obstacles to SHP development in Saudi Arabia are:

- No permanent rivers and very little rainfall make SHP development on natural watercourses a near impossibility;
- Water insecurity stemming from the above factor drives the country to carry out desalination to meet its water supply needs, making any power sector development that requires fresh water abstraction very unlikely;
- Heavy reliance on thermal power from cheaply available domestic fuel sources hinders RES development as a whole.

Possible opportunities for SHP development in Saudi Arabia include:

- The installation of SHP turbines on outflow from existing non-powered dams, yielding a considerable potential SHP capacity;
- Energy recovery solutions utilizing SHP installed on water distribution networks.

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Syrian Arab Republic

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KEY FACTS

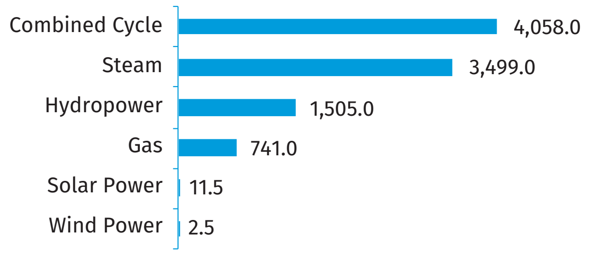
Population	26,262,000 (est. 2020) [1]
Area	185,180 km^2 [1]
Topography	The Syrian Arab Republic lies on the eastern coast of the Mediterranean Sea. Topographically, Syria may be divided into four regions: the coastal region between the Syrian Coastal Mountain Range and the Mediterranean; the mountainous and highlands region that runs from the north down to the south of the country parallel to the Mediterranean Sea; the interior or plains region that comprises the plains of Damascus, Homs, Hama, Aleppo, Hassakeh and Dara'a, and is located east of the mountainous region; and the desert region or Badiah in the south-eastern part of the country. The highest point in the country is Mount Hermon at 2,814 metres above sea level.[2,3]
Climate	A Mediterranean climate generally prevails in Syria, characterized by a rainy winter and a dry, hot summer. Daily differences between the maximum and minimum temperatures are generally quite significant in most parts of the country, sometimes reaching 23 °C in interior areas and 13 °C in coastal areas. The daily fluctuations in temperature are greater in the interior and desert areas as compared with areas on the coast and at high altitudes. December and January are the coldest months of the year, while July and August are the hottest. In winter the temperature frequently falls below 0 °C but rarely below -10 °C, while in the summer it often reaches 48 °C.[2,3]
Climate Change	Ongoing climate change in Syria has resulted in drought, heat waves and dust storms, while climate change impacts on Syria through 2041 are expected to include a reduction in precipitation and rising temperatures. Projections of long-term climate change in Syria based on IPCC climate change scenarios A2 and B2, published in 2010, indicated that the temperature rise in Syria in the coming decades will be higher than the global average. By 2041, a temperature increase of 2.0–2.1 °C is expected for the north-western and south-eastern parts of the country relative to the 1961–1990 baseline scenario, with other regions experiencing an increase of 1.0–1.2 °C. Climate change impacts on internal water resources through the 2050s are projected to cause a 30 per cent decline in groundwater relative to the 1961–1990 baseline period.[3,4]
Rain Pattern	Total annual precipitation in Syria varies highly depending on the region. Annual precipitation ranges from 100 mm to 150 mm in the north-western parts of the country, from 150 mm to 200 mm from the south to the central and east-central areas, from 300 mm to 600 mm in the plains and along the western foothills and from 800 mm to 1,000 mm along the coastal zones, reaching 1,400 mm in the mountains. Average annual rainfall is approximately 250 mm.[3]
Hydrology	Water resources in Syria are limited and distributed among seven basins. The Tenth Five-Year Plan of Syria estimated the total water resources in the country at 15 billion m^3, with 10 billion m^3 of surface water and another 5 billion m^3 underground. There are 16 main rivers and tributaries in the country, mainly located in the northern part of country, with the Euphrates being the largest.[2,3]

ELECTRICITY SECTOR OVERVIEW

The primary indigenous energy resources in Syria are oil, natural gas and limited hydropower resources. The Syrian energy sector is characterized by the dominance of fossil fuels and lack of renewable energy sources (RES). Historically, the energy sector was strategically important for achieving growth in all other sectors of the economy and prior to 2011 the oil and gas sector accounted for approximately one-fourth of the Government's revenue. However, the country's indigenous energy resources are limited and it is expected to become a net oil importer in the foreseeable future even without accounting for the impact of the ongoing conflict. The energy sector of Syria has encountered several challenges as a result of the conflict and subsequent sanctions imposed by the United States and the European Union (EU). The energy infrastructure, including oil and natural gas pipelines and electricity transmission networks, has been damaged, which has hindered the exploration, development, production and transport of the country's energy resources.[4,5,6]

According to the technical statistical report for 2020 prepared by the Public Establishment of Electricity Generation (PEEG), at the end of 2020 the total installed capacity of Syria was 9,803 MW. Of the total, 1,505 MW (15 per cent) was from hydropower plants, while the remaining 8,298 MW (85 per cent) was represented by thermal power plants, including combined cycle turbines with 4,058 MW (41 per cent), steam turbines with 3,499 MW (36 per cent) and gas turbines with 741 MW (8 per cent).[7] Additionally, a number of RES projects not wholly owned by the Ministry of Electricity, and therefore excluded from the PEEG reports, were in operation in 2020. This includes approximately 11.5 MW of solar power located mainly in Tartous and As-Suwayda, as well as a single 2.5 MW wind power plant, bringing the total installed capacity of the country in 2020 to 9,817 MW (Figure 1).[7,8]

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



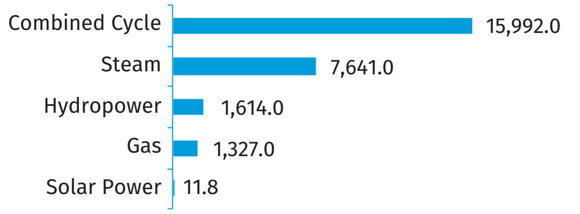
Source: PEEG,[7] Alemam, H.[8]

The last 10 years of crisis and war have heavily affected the country's electricity sector, with many power plants out of service and serious negative impacts on both electricity demand and supply (including available capacity of the system as well as actual generation). Physical damage to electricity infrastructure from the war has been very severe, but the functionality of the transmission grid has so far been largely maintained. Two major thermal power plants (the 1,065 MW Aleppo plant and the 544 MW Zyzoun plant) were fully out of service as of 2020 and in need of deep rehabilitation.[7]

As a result, of the total installed capacity of 9,803 MW reported by PEEG in 2020, less than 5,581 MW was technically available (4,481 MW of thermal power and barely 1,000 MW of hydropower). However, taking into account the severe fuel shortages, the operable capacity may be less than 30 per cent of the technically available total. The available fuel is sometimes barely enough to operate 1,700-2,000 MW.[9]

Total electricity generation in 2020 decreased to approximately 26,586 GWh from more than 49,000 GWh in 2011, a decrease of nearly 46 per cent.[7] In particular, generation by hydropower decreased dramatically, from 2,992 GWh in 2011 to 1,614 in 2020 (a decrease of over 46 per cent). Meanwhile, generation by combined cycle turbine plants in 2020 equalled 15,992 GWh, by steam turbine plants 7,641 GWh and by gas turbine plants 1,327 GWh. Solar power produced almost 11.8 GWh in 2020, while wind power generation was negligible (Figure 2).[7,8]

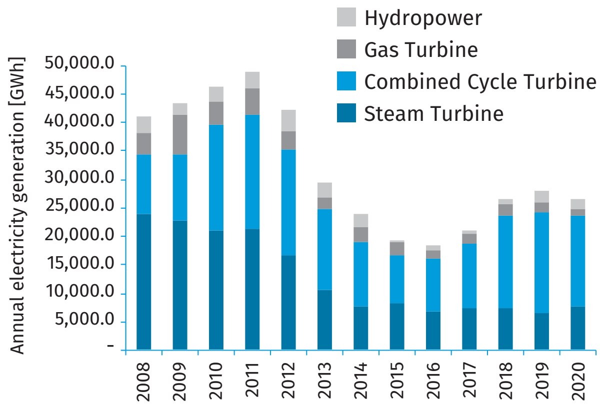
Figure 2. **Annual Electricity Generation by Source in Syria in 2020 (GWh)**



Source: PEEG,[7] Alemam, H.[8]

Historical generation by source over the past decade is displayed in Figure 3. A steep decline in generation can be observed from 2011 to 2016, followed by a partial recovery between 2016 and 2019. Finally, 2020 again recorded a decline in generation that can be partially attributed to fuel shortages caused by a new round of sanctions enacted in 2019 and partially to maintenance constraints, leading to scheduled load shedding throughout the country.[9]

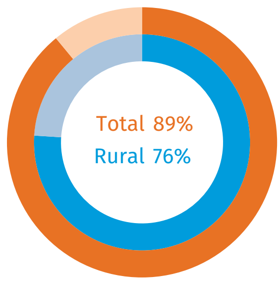
Figure 3. **Annual Electricity Generation by Source in Syria in 2008–2020 (GWh)**



Source: PEEG[7]

Electricity access in Syria was 89 per cent nationally in 2019, but only 76 per cent in rural areas (Figure 4). As with other indicators, electricity access has declined over the past decade, from 93 per cent of overall electricity access and 83 per cent of rural access in 2010.[10]

Figure 4. **Electrification Rate in Syria in 2019 (%)**



Source: World Bank[10]

Hydropower is currently the only significant RES in Syria, providing between 2,000 GWh and 4,000 GWh per year. The hydropower resources in Syria are limited by low precipitation and flow from international rivers.[6,7] Low generation relative to installed capacity is due to the fact that hydropower plants in Syria are operated mostly during the peak load period rather than continuously. The Al-Thawra Dam (800 MW) and Tishreen Dam (630 MW), both on the Euphrates, provide approximately 90 per cent of the hydropower supply. The Al-Baath Dam on the Euphrates (75 MW) and 3 other small, very old hydropower plants with a total capacity of 23 MW make up the 1,528 MW installed capacity total.[6]

The electricity sector in Syria is organized under the Ministry of Electricity, which regulates and manages the sector. PEEG, operating as part of the Ministry of Electricity, is responsible for planning, development, operation and maintenance of the generating plants. The Public Establishment for the Transmission and Distribution of Electricity (PETDE) and its 14 regional branches are responsible for the transmission and distribution network.

However, hydropower plants under the supervision of the General Establishment of Euphrates Dam (the Thawra, Baath, and Tishreen hydropower plants) are supervised by the Ministry of Irrigation.[6,7,11]

While the ongoing situation has prevented large-scale development of RES in Syria, some progress has been made in recent years in the adoption of both on-grid and off-grid solar power. On-grid solar power capacity has increased from a mere 311 kW in 2017 to 11,488 kW in 2020.[8] Solar power projects have been primarily implemented in the north-western region (with the city of Tartous accounting for 57 per cent of the installed capacity), in addition to Hama, Homs, Damascus and suburbs and As-Suwayda in the southern region. Individual installed capacities are rated at below 1 MW in all cases. As of the end of 2020, an additional 117.13 MW of solar power projects had been licensed for construction, including projects intended to supply power to industry in cities, including Aleppo (33 MW) and Homs (30 MW). Moreover, two large solar power projects are under negotiation with private investors, including a 100 MW solar power plant to be constructed in the industrial part of Damascus, as well as a 300 MW solar power plant in Harran Al-Aoamed in the Damascus suburbs. However, the majority of these projects are still in the early negotiation phase, with the exception of the 33 MW solar power plant in Aleppo, which has already commenced construction.[8,9,12,13] Off-grid solar power capacity installed by homeowners and small businesses is hard to quantify. However, it is estimated at two to three times the quoted on-grid capacity, owing to the rising popularity of solar power in providing electricity for water pumping for irrigation and household use.[9]

Electricity tariffs in Syria are subsided and despite periodic adjustments are still below cost recovery level, which does not encourage energy efficiency or more penetration of RES among consumers. Electricity tariffs vary based on the type of consumer, volume of electricity used and voltage. Most electricity subsidies are applied towards household consumption at the lower levels of monthly usage.

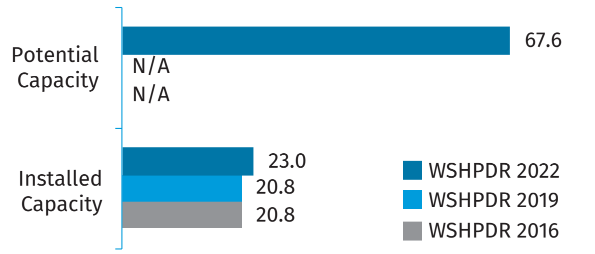
The average electricity tariff rate in Syria has consistently been very low by regional standards — approximately 0.044 USD/kWh before the year 2011 and less than USD0.021/kWh in 2021 (taking into account the current deterioration of the SYP/USD exchange rate, with the official rate set at 1,256 SYP/1 USD). This was comparable to the tariffs in oil and gas exporting countries and significantly lower than the tariffs in regional non-oil rich countries such as Jordan, Lebanon, and Morocco.[9,14]

In this context, a number of studies were carried out to examine the options for tariff adjustment, including an EU-funded project in 2006 and another study within the Electricity Sector Strategy Note prepared by the World Bank at the request of the Government of Syria in 2009. The studies suggested that setting the average long-range marginal cost (LRMC)-based tariff at or above 0.091 USD/kWh and accelerating tariff increases above the rate of inflation would be necessary to achieve self-financing by the electricity utilities. [15,16]

SMALL HYDROPOWER SECTOR OVERVIEW

The definition of small hydropower (SHP) in the Syrian Arab Republic is up to 10 MW.[10] The installed capacity of SHP in Syria of 23 MW has not changed in recent years, while new data on potential SHP capacity suggests a maximum of 44.6 MW of untapped potential capacity and hence 67.6 MW of total SHP potential capacity (Figure 5). Relative to the *World Small Hydropower Development Report (WSHPDR) 2019,* installed capacity has increased by approximately 10 per cent due to more accurate data becoming available.[7,17,18]

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



Source: PEEG,[7] National Committee for Small Hydro Power Potential,[17] *WSHPDR 2019,*[18] *WSHPDR 2013,*[19] *WSHPDR 2016*[20]

According to the annual statistical reports of PEEG published between 2003 and 2020, there are three SHP plants in Syria, with a nominal installed capacity of 23 MW: the Barada Valley SHP plant, the Shezar SHP plant and the al-Rastan SHP plant (Table 1). However, these three plants are very old and primarily operated seasonally, with available capacities additionally fluctuating based on river flow volumes.

For long periods the available capacity of these three plants can actually drop to 0 MW, as happened between 2005 and 2011. An additional SHP plant, the 1.5 MW al-Takkia plant cited in *WSHPDR 2019*, has been entirely out of commission since 1958.[7,9]

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

Name	*Location*	*Capacity (MW)*	*Plant type*	*Operator*	*Launch year*
Al Rastan	Al Assi River	7	Reservoir	PEEGT	1962
Barada Valley	Barada River	8	Reservoir	PEEGT	1957
Shezar	Al Assi River	8	Reservoir	PEEGT	1932

Source: PEEG,[7] Darwich & Almoustafa[9]

During the last decade, and owing to the ongoing shortages in fuel and natural gas supplies and the corresponding negative effects on electricity generation, more attention has been given to developing micro- and small hydropower. In 2020, a national committee was established in Syria to map the potential for SHP exploitation on different rivers and natural water flows, as well as exploring the possibility of producing electricity from outflows of sewage water treatment facilities.[17] The report's findings estimate a considerable SHP potential in the country, including:

- The potential for annual electricity production from outflow of the sewage treatment stations is approximately 53.6 GWh. The report recommended taking advantage of the wide distribution of sewage treatment stations across the country and their proximity to population centres.
- The potential SHP capacity of the rivers of the coastal region of Syria was estimated at 32.3–36.3 MW, including a number of SHP units to be installed at the 16 Tishreen Dam with a 26–30 MW cumulative capacity.
- The viability of replacing pressure breaker valves on water distribution pipes with SHP turbines in three regions of the country was also assessed, estimating the following potential capacities: Damascus and Damascus suburb with 6.1 MW, the coastal region with 3 MW and Homs with 0.67 MW.[17]

Table 2 provides a summary of potential SHP sites and projects in Syria, including the projects examined by the aforementioned study as well as the defunct Al-Takkia SHP plant that may present an opportunity for refurbishment. The total assessed SHP potential capacity of the listed projects is approximately 40.6–44.6 MW, while the potential annual generation is 221.6 GWh.[9,17] Further studies are necessary to analyze the scope for small and micro-hydropower in the country, in particular studies on standalone power plants as well as on power plants linked together to form regional mini-grids.

Table 2. **List of Potential Small Hydropower Sites in Syria**

Name	*Location*	*Potential capacity (MW)*	*Potential annual generation (GWh)*
16 Tishreen Dam (multiple SHP units)	Coastal	26.0–30.0	84.0
Al-Thawra	Coastal	1.5	2.3
Baloran	Coastal	0.3	0.9
Al-Basel	Coastal	1.5	4.3
Al-Takkia	Al-Assi River	1.5	N/A
Sewage Water Treatment Stations	Nationwide	N/A	53.6
Pressure Breaker Valves	Coastal	3.0	26.3
	Damascus	6.1	44.3
	Homs	0.7	5.9
Total		**40.6–44.6**	**221.6**

Source: Darwich & Almoustafa,[9] National Committee for Small Hydro Power Potential[17]

RENEWABLE ENERGY POLICY

Presently, electric power generation from RES in Syria includes SHP, large hydropower, solar power and one wind power plant. Attempts to formulate an appropriate RES policy framework have taken place over the last decade despite the ongoing war, aiming to overcome the existing barriers and promote implementation of RES generation options.

Studies suggest that Syria has a high untapped potential with regard to wind and solar power. The wind power potential in Syria is very promising, as annual mean daily wind speed in some regions of the country reaches 13 m/s.[21] The theoretical wind energy potential in Syria is estimated at 40 GW, with approximately 12 GW considered a practical achievable upper limit for all energy purposes, including electricity generation.[2,22] Moreover, Syria, like other Mediterranean countries, is rich in solar irradiation, with average solar irradiation on a horizontal surface ranging between 4.4 kWh/m^2 per day in the mountainous region to 5.2 kWh/m^2 per day in the Syrian desert. The sun shines approximately 2,800–3,200 hours per year and there are only approximately 40 cloudy days per year.[5,6,21,23,24]

Aiming to take advantage of these resources, Syria adopted measures in 2011 to attract investor interest in RES. It has opened its market for private developers, adopted feed-in tariffs (FITs) and a net metering policy subsidized by the state, authorized the business-to-business sale of renewable electricity and announced tenders for public competitive bidding to develop the first large-scale wind power projects.[21] FITs are subsidized by the Government. As of 2020, tariffs were set at the levels indicated in Table 3, as per Government of Syria Resolution 1113. Tariffs for solar energy projects are guaranteed for a 25-year period.[9]

Table 3. **Feed-in Tariffs for Electricity Generation in Syria in 2020**

Source type	*Rate (USD/kWh)*
Solar photovoltaic (PV) power	0.082
Hybrid solar PV and wind power	0.076
Wind power	0.070
Hydropower	0.070
Biomass	0.067
Landfill gas	0.067

Source: Darwich & Almoustafa[9]

A major factor driving investment in solar power in Syria is the adoption of the National Renewable Energy Strategy to 2030 in 2019. In accordance with this strategy, the contribution of RES to the energy balance is targeted to reach 5 per cent of the total primary energy demand by 2030, while the annual electricity generation from solar PV and wind power plants is expected to meet approximately 7 per cent of the energy demand by 2030. Specific targets include 1,500 MW of solar PV projects, 900 MW of wind turbines and 1.2 million solar heaters.

The ambitious RES plan will be implemented through several means and in cooperation with a wide range of partners. The projects will consist of turn-key projects carried out by the Ministry of Electricity, investment projects carried out by the private, public and joint sectors and projects implemented by electricity consumers, including the agricultural, water resources, industrial, commercial, domestic, government and management sectors as well as places of worship. Additionally, certain waste and solar heater projects are expected to be funded through the Renewable Energy Support Fund.

The more decentralized distribution of RES-based generation compared to fossil fuel-fired power plants will require reconfiguration of the national electricity grid to better integrate power inputs from sources with high output variability and to reduce transmission losses from the more remote RES electricity generation sites.

Apart from the currently unfavourable security situation, the main challenges in developing RES in Syria arise from the socioeconomic impact of technology replacement, energy prices and subsidies that are below the cost recovery level, lack of public awareness, the current regulatory framework and insufficient public financial support.[9,25]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Climate change and water use patterns have put increasing pressure on the water resources in Syria in recent decades, with consumed water exceeding available water resources by as much as 30 per cent in the early 2000s, compared to a nearly 1-to-1 ratio in the early 1990s. A decline in groundwater levels has taken place in parallel with decreasing surface water availability. In one stark example, the Khabour River, the largest tributary of the Euphrates in Syria, went completely dry in 1999, having experienced a continuous decline in flow since the 1970s. Another major river, the Barada, is expected to experience a 37 per cent decline in flow at the source by 2039, relative to 2006–2007. Overall, the deficit in water resources is projected to increase by 200 per cent by 2027, relative to the observed deficit during the 1995–2005 period.[3]

In Syria, over 90 per cent of water use is dedicated to agriculture.[3] As such, the demands of the agricultural sector can be expected to compete with hydropower water demand in the foreseeable future.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Some of the most important barriers to SHP development in Syria are outlined below:

- Hydropower resources of all sizes are limited by low precipitation and river flows, with most of the available hydropower potential having already been utilized;
- The current conflict situation has put almost all development plans on hold;
- A lack of detailed studies on the potential for small and micro-hydropower; additional studies must be conducted, in particular on the interconnectivity of SHP plants along mini-grids.

Enablers for SHP development include:

- Insecurity of access to fossil fuels, which have traditionally formed the mainstay of the electricity generation sector in Syria, prompting the need to develop alternatives;
- Recent surveys point to various forms of untapped SHP potential existing in Syria, including potential for energy recovery projects built on existing water infrastructure.

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Turkey

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KEY FACTS

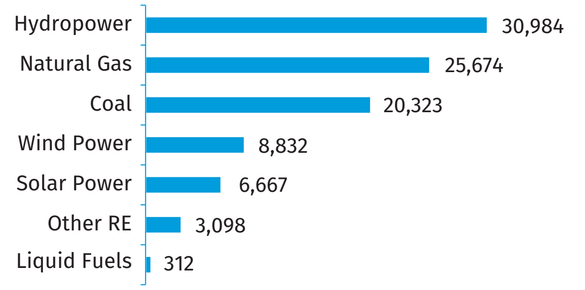
Population	83,614,362 (2020)[1]
Area	814,572 km^2 [2]
Topography	Despite the existence of broad plains and plateaus, the topography of Turkey is largely hilly and mountainous across the entire territory. The central Anatolian Plateau dominates the territory, with the exception of narrow coastal plains on the Aegean and Black Seas. Turkey has one peak of over 5,000 metres in altitude (Mount Ararat), three over 4,000 metres and 219 peaks exceeding 3,000 metres. Turkey lies within a seismically active area.[3]
Climate	The climate in Turkey is semi-arid. Coastal areas have a Mediterranean climate with hot and dry summers between June and August and temperatures reaching 35 °C. In the higher interior Anatolian Plateau, the winter months (between December and February) can be very cold, with temperatures reaching -7 °C. In the period between 2008 and 2017, the mean temperature was 13.9 °C.[4]
Climate Change	Turkey is highly vulnerable to climate change and is already facing an observed warming trend in temperatures and a decreasing trend in precipitation. This is having a major negative effect on water availability for food production and rural development, further exacerbating the social and regional disparities in a country characterized by a wide (and widening) gap between the eastern and south-eastern provinces and the rest of the country.[5]
Rain Pattern	The average annual rainfall in Turkey is 574 mm, but in some years, it is lower due to drought and climate variation. The Eastern Black Sea region receives the most rainfall (1,200–2,500 mm/year), while the Central Anatolia region (around Salt Lake) receives the least rainfall (250–300 mm/year). In other parts of Turkey, except for coastal settlements in the Mediterranean and South Aegean regions, snowfall occurs during the winter months. Approximately 70 per cent of the total precipitation occurs between October and April.[4]
Hydrology	Turkey is divided into 25 river basins. Most rivers originate in Turkey and there are more than 120 natural lakes, 293 dam reservoirs and about 1,000 small dam reservoirs. Possessing 28 per cent of the country's water potential, the Euphrates–Tigris River basin is the largest basin in terms of both surface area and water potential. The Euphrates and the Tigris have their sources in the high mountains of north-eastern Anatolia and flow through Turkey before entering the Syrian Arab Republic. These two rivers account for approximately one third of the water potential of Turkey. Many rivers rise and discharge into seas within the country's borders. The rivers discharging into the Black Sea are the Sakarya, Filyos, Kızılırmak, Yeşilırmak and Çoruh. Meanwhile, the Asi, Seyhan, Ceyhan, Tarsus (Berdan) and Dalaman discharge into the Mediterranean Sea; the Büyük Menderes, Küçük Menderes, Gediz and Meriç into the Aegean and the Susurluk/Simav, Biga and Gönen into the Sea of Marmara.[6]

ELECTRICITY SECTOR OVERVIEW

Turkey could provide itself completely with self-produced energy. As of 31 December 2020, its total installed capacity stood at 95,890 MW compared to 69,516 MW in 2014.[7,8] The installed capacity increased thanks to the installation of new natural gas, solar power, hydropower and wind power plants. Within the energy mix, hydropower has become the primary source in Turkey, accounting for over 32 per cent of the installed capacity. As for the other energy sources, 27 per cent of installed capacity comes from gas-fired power plants, 21 per cent from coal-fired plants (hard coal and lignite), 9 per cent from wind power, 7 per cent from solar power, 2 per cent from other renewable sources (geothermal power and waste heat), 1 per cent from biomass and 0.3 from other fuels (oil, diesel, naphtha) (Figure 1). Thus, at the end of December 2020, the share of renewable energy in the country's total installed capacity exceeded 50 per cent.[7,8]

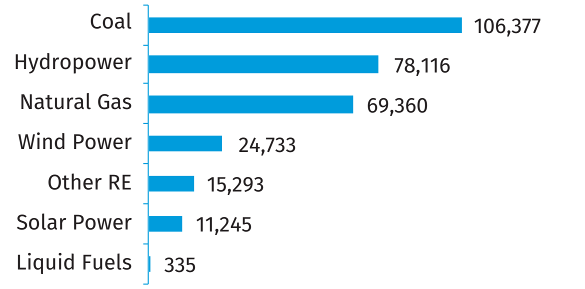
In 2020, total annual electricity generation in Turkey amounted to 305.5 TWh. Within total power generation, coal had the dominant role contributing almost 35 per cent, hydropower 26 per cent, natural gas 23 per cent, wind and solar power 12 per cent combined and geothermal power and biomass 3 and 2 per cent, respectively (Figure 2). Overall, roughly 58 per cent of electricity generation was obtained from fossil fuel sources and 42 per cent from renewable sources. In the same year, Turkey imported 1,888 GWh and exported 2,484 GWh of electricity.[7,8]

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



Source: EMRA,[7] Chamber of Electrical Engineers[8]

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



Source: EMRA,[7] Chamber of Electrical Engineers[8]

Compared to 2019, electricity generation in 2020 increased by 7.8 per cent and electricity consumption by 5.8 per cent. The share of the installed capacity and electricity generated from privately-owned plants has been rising steadily since 2006. While the share of the public sector in installed capacity was 60 per cent and that of the private sector 40 per cent in 2006, by 2020, the share of the private sector in installed capacity was 78 percent and that of the public sector 22 per cent, while in electricity generation the shares were 82 per cent and 18 per cent, respectively. More than half of electricity (57 per cent) is generated using domestic sources and the rest is from imported energy sources.[7,8] The electrification rate across the country is 100 per cent.

The Electricity Market Law No. 6446 (EML) introduced on 30 March 2013 is still the main law applicable to the Turkish electricity market. The EML regulates the obligations of all real persons and legal entities directly involved in the generation, transmission, distribution, wholesale supply, retail supply, import and export of electricity in the country. The implementation and interpretation of new mechanisms introduced by the EML are outlined in secondary legislation, among which the most notable piece is the Electricity Market Licensing Regulation (Licensing Regulation) published on 2 November 2013. The Licensing Regulation introduced a new licensing regime, intended to reform and stimulate the market.[9,10]

In Turkey, there are two main governmental authorities regulating the electricity market, the Ministry of Energy and Natural Resources (MENR) and the Energy Market Regulatory Authority (EMRA). The electricity market can be subdivided into the generation, transmission, market operation and distribution functions. Turkish Electricity Transmission Corporation (TEIAS) owns and operates the electricity transmission system, while distribution is divided into 21 separate regions. Each region is controlled by private distribution companies each with distribution licences issued by EMRA. EMRA is responsible for issuing licences to all electricity suppliers. There are 1,656 licensed generation companies, 21 private distribution companies operated by private sector, 21 assigned private suppliers with duty of last resort and one state-owned wholesaler Electricity Generation Company (EÜAŞ). The private sector plays an important role in the electricity market. The private sector's share in licensed installed capacity is approximately 80 per cent, including Build Operate Transfer (BOT) and Transfer of Operating Rights (TOOR) contracts.[11,12]

Before the introduction of the EML, TEIAS was both a system and market operator. Since 2018 however, TEIAS has operated solely as the transmission system operator (TSO), while a new company, the ISTANBUL ENERGY EXCHANGE (EPIAS), was established as a market operator. EPIAS's shareholders are represented by 30 per cent each by TEIAS and by Istanbul Exchange Market (BIST) and 40 per cent by the private sector. EPIAS, as the market operator, is responsible for organizing the energy exchange market operations and operates the spot market to allow the private sector to make forecasts more easily in order to plan their investments.[13]

Turkey has been experiencing a rapid growth of demand in all segments of the energy sector for decades. Forecasts indicated that this trend will continue in the forthcoming decades in parallel with the economic and social development. The main target of the Turkish energy policy has been to provide timely, reliable and sufficient energy, meeting the rapidly growing demand, at affordable prices and in an environmentally sound manner.[14] In 2017, Turkey announced the National Energy and Mining Strategy to strengthen the confidence in the industry and to update the country's goals for the sector. Ensuring energy supply security and predictable market conditions as well as localization are the three pillars of strategy in this sector. Thus, Turkey aims to promote the use of domestic energy resources and reduce import dependency. As part of this effort, the 11th Development Plan (2019–2023) sets out targets to achieve 219.5 TWh of electricity production from domestic resources, based on total electricity demand of 375.8 TWh, by 2023. As part of this projection, Turkey plans to commission 10,000 MW each of solar and wind power capacity in 2017–2027.[12]

As of January 2021, electricity prices per kWh in Turkey were USD 0.094 for household consumers, USD 0.13 for commercial enterprises and USD 0.11 for industrial enterprises.[15]

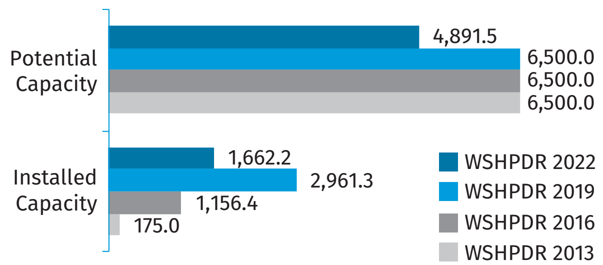
Figure 4. **Distribution of Small Hydropower Plants in Turkey by Province**

Source: DSI[16,17]

SMALL HYDROPOWER SECTOR OVERVIEW

Although there is no legal definition in Turkey, hydropower plants with an installed capacity of less than 10 MW are widely considered as small hydropower (SHP). As of the end of 2020, there were 351 SHP plants in operation. Of these, 14 are operated by the DSI and 337 are operated by the private sector. The installed capacity of the operating SHP plants is 1,662.2 MW, their total generation potential is 6,279,926 GWh/year. A further 38 SHP plants were under construction at the end of 2020 (Table 1).[16] In addition, 613 SHP projects with a combined installed capacity of 2,594.3 MW and generation potential of 8,569,956 GWh/year were cancelled. These cancellations were due to a number of factors, including: technical and economic difficulties, challenges associated with obtaining licences and other necessary planning permissions, and environmental factors such as drought. The decrease in installed capacity since the *World Small Hydropower Development Report (WSHPDR) 2019* is due to access to new and updated datasets (Figure 3). The decrease in potential capacity is due to new economic potential estimates from State Hydraulic Works.[16,17]

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



Source: DSI,[16,17] *WSHPDR 2013*,[17] *WSHPDR 2016*,[18] *WSHPDR 2019*[19]

Table 1. **Overview of Small Hydropower in Turkey as of December 2020**

Stage of project	*Owner (public/private)*	*Number*	*Installed capacity (MW)*	*Generation potential (GWh/year)*	*Share of total (%)*
Operational	DSI (public)	14	42.57	145,100	0.9
	Private	337	1,619.63	6,134,826	35.8
	Total	351	1,662.20	6,279,926	36.7
Under construction	DSI (public)	19	101.83	368,389	2.2
	Private	19	101.83	368,389	2.2
	Total	38	202.66	736,778	4.4
Inspection and feasibility study	Private	70	355.98	1,229,931	7.7
	DSI (prelicence -Planned)	6	31.19	94,290	0.3
	Total	76	287.17	1,325,221	8.0
Total potential (operation-construction-inspection-project)		*476*	*2,297.16*	*8,493,338*	*49.9*
Cancelled SHP projects		613	2,594.29	8,569,956	50.1
Total SHP potential		**1,089**	**4,891.45**	**17,063,294**	**100**

Source: DSI[16,17]

Regionally, 34 per cent of SHP plants (120 plants) are located in the Black Sea region of the country; 21 per cent (74 plants) in the Mediterranean region; 16 per cent (55 plants) in the Eastern Anatolia region; 14 per cent (48 plants) in the Central Anatolia region; 9 per cent (30 plants) in the Marmara region and 6 per cent (21 plants) in the Aegean region (Figure 4).[16,17]

Table 2 and Table 3 show lists of selected operational and ongoing SHP projects in Turkey, respectively.

Table 2. **List of Selected Operational Small Hydropower Plants in Turkey**

Name	*Location*	*Capacity (MW)*	*Plant type*	*Operator*	*Launch year*
Eastern	Bingol	10.0	–	Nassan Electricity Generation	–
Boğazköy	Bursa	10.0	–	Burgüç Bursa Collaboration	2005
Yesilvadi	Hatay	10.0	–	Koçoğlu Construction Energy	2013
Balıklı 1, 2 & 3	Artvin	9.8	–	Assu Electric Energy Generation	–
Sölperen	Erzincan	9.8	–	Vasfi Energy	2013 (?)
Kuyma	Samsun	9.7	Run-of-river	Kuyuma Elk. Ürt. A.Ş.	2020
Kıran	Giresun	9.7	–	Arsan Energy	–
Adasu	Sakarya	9.6	–	Sakarya Metropolitan Municipality	2013 (?)
Kale	Rize	9.6	–	Bahser Energy	2010
Berke	Kastamonu	9.4	–	Elbi Energy	2014
Hasanlar	Duzce	9.3	Dam	Batıçim Energy	2011
Esendurak	Erzurum	9.3	–	Meral Electricity Generation	2012
Alicik I-II	Rize	9.0	Run-of-river	Baro Elektrik Üretim A.Ş.	2020
Çarıklı	Amasya	9.0	–	Delta Investment Holding	–
Telli	Giresun	8.7	–	Bahser Energy	2012
Karakuş	Adıyaman	8.2	Run-of-river	Murat HES Enerji Elektrik Üretim ve Tic. Ltd. Şti.	2020
Kirazlıköprü	Bartın	8.0	Dam	MHM Turkey Makine Tic. Ltd. Şti.	2020
Kuzkaya	Kastamonu	6.5	Run-of-river	Murat Kaan Elektrik Üretim A.Ş.	2020
Hacımercan	Sakarya	5.4	Irrigation channel	Akım Enerji A.Ş.	2020
Araklı Kaçkar	Trabzon	3.9	Run-of-river	İpek Enerji San. ve Tic. Ltd. Şti.	2020

Source: Enerji Atlas[20]

The total hydropower potential of Turkey is estimated at 55,000 MW. According to MENR's Strategic Plan 2019–2023, by 2023 installed hydropower capacity is to reach 32.9 per cent of the country's total installed capacity (approximately 32 GW).[14,22]

Table 3. **List of Selected Ongoing Small Hydropower Projects in Turkey**

Name	*Location*	*Capacity (MW)*	*Plant type*	*Developer*	*Planned launch year*	*Development stage (% completed)*
Kutay	Tokat	7.05	Run-of-river	Arc Elektromek. Enerji San. ve Tic. Ltd. Şti.	N/A	85
Bingöl I	Bingöl	7.75	Run-of-river	Ant Karlıova Elk. En. Ürt. Ltd. Şti.	2022	70
Düzköy	Trabzon	6.12	Run-of-river	ADV Elk. Ürt. Ltd. Şti.	2021	45
Zilan	Van	6.07	Run-of-river	Zilan Elektrik Üretim A.Ş.	2021	22
Adadağı	Giresun	7.17	Run-of-river	Değirmenyanı Enerji Üretim Ticaret A.Ş.	2020	10

Source: DSI[21]

Table 4. **Hydropower Status in Turkey as of 31 December 2020**

Stage of project	*Owner (public/private)*	*Number*	*Installed capacity (MW)*	*Generation potential (GWh/year)*	*Share of total (%)*
Operational	DSI (public)	68	13,766	48,952	27.2
	Private	646	17,625	59,053	32.8
	Total	714	31,391*	108,005	50
Under construction	DSI (public)	2	700	2,569	1.4
	Private	35	579	2,009	1.1
	Total	37	1,279	4,578	1.5
Inspection and feasibility study	Private	210	8,120	21,680	12.0
	DSI (prelicence-planned)	42	1,574	4,704	2.6
	Total	252	9,194	26,384	14.6
Total potential (operation-construction-inspection-project)		1,003	41,864	138,967	77.1

Source: DSI[16]

Note: *the discrepancy with between these data and Figure 1 is due to the different sources.

Through public-private cooperation, 714 hydropower plants (public and private) with an installed capacity of 31,391 MW and a power generation potential of 108 TWh have been completed and put into service (Table 4). Construction of public sector SHP projects is carried out by DSI (State Hydraulic Works) and the operation is then transferred to EÜAŞ. For SHP projects developed and constructed by the private sector, except for those with an EMRA licence, the DSI may be responsible for a combination of the following: water use agreements, project coordination, construction, water structures acceptance, etc.[23]

RENEWABLE ENERGY POLICY

Turkey is very rich in hydropower, geothermal, solar and wind power resources. Accordingly, development of renewable energy in Turkey is highly encouraged. The national 2023 targets for renewable energy according to national energy policies and strategy documents are as follows:

- In the 11th Development Plan (adopted in 2019), to increase the share of renewable energy sources in total electricity generation to 38.8 per cent.[23]
- In the National Energy and Mining Policy Document (adopted in 2017), to increase electricity generation from renewable energy sources to at least 30 per cent.[12,24]
- The goals of MENR for the year 2023 in the 2019–2023 Strategic Plan included the following:
  - Wind energy installed capacity target is 11,883 MW;
  - Solar energy installed capacity target is 10,000 MW;
  - Hydropower installed capacity target is 32,037 MW;
  - Geothermal and biomass installed capacity target is 2,884 MW.

The set targets for the share of renewable energy in total electricity generation have already been exceeded.

The support mechanism available for renewable energy projects in Turkey is called YEKDEM. It started to be implemented in 2011.[25] Currently, power plants built from 2005 (when the Law on Renewable Energy Sources 5346 was issued) to 2021 can apply for the mechanism. The mechanism consists of two parts: the feed-in tariff (FIT) prices based on the type of renewable energy and the additional FIT price related to locally manufactured equipment usage. These prices are 73 USD/MWh for wind power and hydropower, 133 USD/MWh for solar power and biomass and 105 USD/MWh for geothermal power.[26]

To participate in the YEKDEM scheme, developers must apply to the EMRA after the commissioning of the project in October for following year and cannot quit the mechanism in the year which they applied for. There is no obligation to participate in the mechanism. Projects which are commissioned before 30 June 2021 can benefit from YEKDEM for 10 years.[27] On 30 January 2021, the President's Decision No. 3453 extended the YEKDEM support mechanism for renewable energy-based electricity generation projects for the period from 1 July 2021 to 31 December 2025.[28] Accordingly, the new YEKDEM prices will be 0.40 TL/kWh (0.046 USD/kWh) for hydropower, 0.32 TL/kWh (0.037 USD/kWh) for wind and solar power and 0.54 TL/kWh (0.062 USD/kWh) for geothermal power.[29]

The local content support, which is provided for in Law No. 5346 and may be considered as an extra bonus, is added to the YEKDEM prices of the relevant renewable energy generation plant. This additional tariff is provided for a term of five years from the starting date of operation.[25,28]

Designated forested areas, land privately owned by the Treasury or land under the disposal of the state in its entirety can be utilized for the purposes of renewable energy generation if permission is granted by the Ministry of Agriculture and Forestry or the Ministry of Treasury and Finance. Renewable energy generation plants are not charged the Forestry Peasant Development Revenue or the Forestation and Erosion Control Revenue. Permission, lease, easement and usufruct permission fees are discounted by 85 per cent for renewable energy generation projects during the initial 10 years of investment and operation of power transmission lines, including those in operation. Pursuant to Provisional Article 4 of the Electricity Market Law No. 6446, for all types of generation plants (including renewable energy ones) that will be operational by 31 December 2025, transmission system usage fees are discounted by 50 per cent for the first five years of operation. Additionally, pursuant to Article 43.4 of the Electricity Licensing Regulation, for the power plants generating electricity from local natural resources and renewable sources, the licence holders are not required to pay the yearly licence fees for the first eight years following the date of completion of the power plants.[30]

Under the Renewable Energy Resources Zone (REZ/YEKA) model, which defines the process of Renewable Energy Zones where fixed capacity is tendered, by 2021, 2,000 MW of wind power capacity and 1,000 MW of solar power capacity competitions had been completed. Additionally, in March 2021 the small-scale REZ method was implemented for solar power for the first time. Within this framework, it is decided to hold 74 separate REZ competitions in 36 provinces with 10 MW, 15 MW and 20 MW capacities on auction. The total competition capacity will be 1,000 MW, with 709 applications for solar tenders received in March 2021.[31]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

The realization of SHP projects starts with a study process. The Hydroelectric Energy Department studies the feasibility reports for planned hydropower projects and, taking their rentability into consideration, posts the economically feasible ones on its website for a bid meeting. The applicant companies submit the required documents to DSI and are afterwards invited to a DSI meeting in order to bid.[32] After the meeting, the company that will carry out the project is decided. In the next process, the company prepares a detailed feasibility report and submits it to DSI for approval. After the completion of the process of an environmental impact assessment, a water usage rights agreement between DSI and the company is signed and the developer moves to the construction phase. Throughout the construction phase, the Hydroelectric Energy Department supervises the project. After the completion of the project, the Hydroelectric Energy Department with some other DSI departments makes a pre-final inspection.[16,33] If the plant passes that inspection, it is commissioned and will be granted permission to generate electricity (Figure 5).[17]

Small-scale power plants using renewable sources up to 5 MW and micro-co-generation plants have been exempted from obligations for receiving a licence and establishing a company.[30]

COST OF SMALL HYDROPOWER DEVELOPMENT

An average run-of-river hydropower plant costs USD 1.5 million per MW of installed capacity. Price per unit of generation varies tremendously due to very different precipitation regimes in different parts of the country.

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

Private developers of SHP projects are responsible for finding the required capital for the investment and can use finance options offered by banks. After the commissioning of a plant, the Government offers a fixed purchase price for electricity under the YEKDEM mechanism.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Changes in natural water circle caused by climate change have had and will have impact on hydropower generation. The effect of climate change on SHP is mostly influenced by the change in the river runoff, with the changes in precipitation and temperature being the key driving factors. The increase in the frequency of extreme weather events will also create pressures on hydropower production.[34,35]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Over the past years, installed SHP capacity in Turkey has steadily increased. However, SHP still has to face barriers of different types:

- Legal: Renewable Energy Law No. 5346 applies to SHP or hydropower plants with a reservoir area of less than 15 km^2, making no limitation regarding installed capacity. This guideline encourages the private sector to move towards investment in large hydropower projects for potentially higher profits;
- Environmental: Turkey is among the countries most affected by climate change and variability. As a result, SHP investments are adversely affected due to the decrease in surface waters;
- Social: public opinion against hydropower could affect the investors, due to wrong or inappropriate site selection, exclusion of stakeholders and unplanned basin management.

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

- A pre-existing SHP sector;
- Institutional support for the sector.

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Figure 5. **Process of Hydropower Project Realisation in Turkey**

Source: DSI[17]

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