UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

INTERNATIONAL CENTER
ON SMALL HYDROPOWER

World Small Hydropower Development Report 2022

Eastern Asia

Disclaimer

The World Small Hydropower Development Report 2022 is jointly produced by the United Nations Industrial Development Organization (UNIDO) and the International Center on Small Hydro Power (ICSHP) to provide development information about small hydropower.

The opinions, statistical data and estimates contained in signed articles are the responsibility of the authors and should not necessarily be considered as reflecting the views or bearing the endorsement of UNIDO or ICSHP. Although great care has been taken to maintain the accuracy of information included in the document, neither UNIDO and its Member States, nor ICSHP assume any responsibility for consequences that may arise from the use of the material.

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the UNIDO Secretariat concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as 'developed', 'industrialized' and 'developing' are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

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

Table of Content

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

WSHPDR2022 team

Head	LIU Heng — Senior Technical Advisor, United Nations Industrial Development Organization (UNIDO)
Coordinators	Oxana Lopatina — International Center on Small Hydro Power (ICSHP)
	Eva Krēmere — United Nations Industrial Development Organization (UNIDO)
Team	UNIDO: Eva Krēmere, Sanja Komadina. Interns: LIU Fangjie, REN Wenxuan
	ICSHP: HU Xiaobo, Oxana Lopatina, Danila Podobed, Alicia Chen Luo, Veronika Spurna, Tamsyn Lonsdale-Smith, Bilal Amjad, Oluwatimilehin Paul Olawale-Johnson, Davy Rutajoga, Laura Stamm, YUAN Ruize, BAO Lina, ZHANG Yingnan, DING Yan

Editorial Board

Jesse Benjaman (PCREEE), Alfonso Blanco-Bonilla (OLADE), Cristina Diez Santos (Open Hydro), Tareq Emtairah (UNIDO), Geraldo Lúcio Tiago Filho (CERPCH), Guei Guillaume Fulbert Kouhie (ECREEE), Dirk Hendricks (EREF), Wim Jonker Klunne (Hydro4Africa), Arun Kumar (IIT Roorkee), LIU Deyou (ICSHP), LIU Heng (UNIDO), LIU Hongpeng (UNESCAP), Eddy Moors (IHE Delft Institute for Water Education), Niels Nielsen (Kator Research Services), Mohamedain Seif Elnasr (COMESA), María Ubierna (Open Hydro), XING Yuanyue (Ministry of Water Resources of China)

Peer Reviewers

Joan Cecilia C. Casila, Choten Duba, Mohammad Hajilari, Michela Izzo, Annabel Johnstone, Dimitar Kisliakov, Wim Jonker Klunne, Arun Kumar, Sarah Kwach, Kristian Dahl Larsen, Charlene Monaco, Niels Nielsen, Victor Odundo Owuor, Emanuele Quaranta, Nicolae Soloviov, Fujimoto Tokihiko, Leandro Zelaya

Contributing Experts

Arturo Alarcon, Sameer Algburi, Alsamaoal Almoustafa, Gabrial Anandarajah, Vicky Ariyanti, Fredrick Arnesen, Engku Ahmad Azrulhisham, Ayurzana Badarch, BAO Lina, Mathieu Barnoud, Alexis Baúles, Sow Aissatou Billy, Alaeddin Bobat, Frank Charles Ramírez Bogovich, Ejaz Hussain Butt, Abou Kawass Camara, Jose Campos, Joan Cecilia C. Casila, Piseth Chea, Julian Chin, Salim Chitou, Gift Chiwayula, Brenda Musonda Chizinga, Nouri Chtourou, Romao Grisi Cleber, Ryan Cobb, Poullette Faraon Chaul Corona, John Cotton, Slobodan Cvetkovic, Manana Dadiani, Asger Dall, Bassam Al Darwich, Denise Delvalle, Tobias Dertmann, Gabriel Chol Dhieu, Jonas Dobias, Aurélie Dousset, Choten Duba, José Rogelio Fábrega Duque, Nadia Eshra, Cayetano Espejo Marín, Paola Estenssoro, Soukaina Fersi, Geraldo Lúcio Tiago Filho, Danilo Fras, Fujimoto Tokihiko, Patrick Furrer, Camila Galhardo, Ramón García Marín, Adnan Ghafoor, Gaëlle Gilboire, Zelalem Girma, Mohammad Hajilari, Geon Hanson, Richard Hendriks, Mabikana Voula Boniface Hervé, Yan Huang, Chinedum Ibegbulam, Michela Izzo, Jamal Jaber, Gordana Janevska, Sergio Armando Trelles Jasso, Rim Jemli, Marco Antonio Jimenez, Annabel Johnstone, Julien Jomaux, Wim Jonker Klunne, Abdoul Karim Kagone, John K. Kaldellis, Bryan Karney, Raul Pablo Karpowicz, Egidijus Kasiulis, Shorai Kavu, Eleonora Kazakova, Joseph Kenfack, Dong Hyun Kim, George Kimbowa, Dimitar Kisliakov, Maris Klavins, Ioannis Kougias, Rastislav Kragic, Arun Kumar, Sarah Kwach, Kristian Dahl Larsen, Seung Oh Lee, Jean-Marc Levy, Bryan Leyland, Laura Lizano, Galina Livingstone, Kimberly Lyon, Sarmad Nozad Mahmood, Ewa Malicka, Pedro Manso, Andrés Teodoro Wehrle Martínez, Anik Masfiqur, Mareledi Gina Maswabi, Hamid Mehinovic, Juan José García Méndez, Luiza Fortes Miranda, Guram Mirinashvili, Julio Montenegro, Bastian Morvan, Reynolds Mukuka, Béla Munkácsy, Patricio Muñoz, Wakati Ramadhani Mwaruka, Thet Myo, N'guessan Pacôme N'Cho, Sea Naichy, Niels Nielsen, Gilbert Nzobadila, Emna Omri, Karim Osseiran, Sok Oudam, Victor Odundo Owuor, Grant Pace, Aung Thet Paing, Hok Panha, Sotir Panovski, Ahmet Penjiev, Georgy Petrov, Alexandra Planas, Bogdan Popa, Cecilia Correa Poseiro, Sunil Poudel, Ravita D. Prasad, Kenneth Bengtson Tellesen Primdal, Leonardo Peña Pupo, Thoeung Puthearum, Emanuele Quaranta, Samira Rasolkhani, Atul Raturi, Thomas Buchsbaum Regner, António Carmona Rodrigues, Jorge Saavedra, Najib Rahman Sabory, Victor Sagastume, Esmina Sahic, Alberto Sanchez, Karine Sargsyan, Vahan Sargsyan, Goran Sekulić, Ozturk Selvitop, Shamsuddin Shahid, Stafford W. Sheehan, Manish Shrestha, Sangam Shrestha, Mundia Simainga, Gjergji Simaku, Martin Sinjala, Seming Skau, Nicolae Soloviov, Amine Boudghene Stambouli, Dmytro Stefanyshyn, Pavel Štípský, Jean Sumaili, Dinesh Surroop, Areli Sutherland, Alberto Tena, Pierre Kenol Thys, Anastasiya Timashenok, Panagiotis Triantafyllou, Alexander Urbanovich, Joelinet Vanomaro, Goran Vasilic, Ciza Willy, Ernesto Yoel Fariñas Wong, Gendensuren Yondongombo, Saida Yusupova

Eastern Asia

Countries: China, Democratic People's Republic of Korea, Japan, Mongolia, Republic of Korea

INTRODUCTION TO THE REGION

In Eastern Asia, the large and highly diversified electricity sectors of China, Japan and the Republic of Korea (RoK) contrast with those of Mongolia and the Democratic People's Republic of Korea (DPRK), which are comparatively smaller and less diversified. In China, the electricity grid is operated by two state-owned companies. While thermal power remains the dominant energy source, renewable energy sources including hydropower and wind power are expanding as part of the country's energy transition. The electricity sector in the DPRK is entirely state-owned and largely reliant on hydropower and thermal power. By contrast, the electricity sector of Japan is dominated by 10 large regional power utilities, with hundreds of smaller companies entering the electricity market following years of gradual liberalization. In the RoK, nearly 100 per cent of electricity is produced by public utilities, although private electricity companies have a significant presence. Both countries utilize a mix of thermal power sources in addition to nuclear power and renewable energy sources. The electricity sector of Mongolia is fully state-owned. Unlike other countries in Eastern Asia, Mongolia is highly dependent on electricity imports, receiving approximately 20 per cent of its electricity from Russia and China, while domestic generation is heavily dominated by coal-fired power plants.

All countries in the Eastern Asia region possess considerable hydropower capacities, with the exception of Mongolia. Hydropower is the leading source of power generation in the DPRK in terms of installed capacity and second in terms of annual generation. In China and Japan, hydropower plays a supporting role, accounting for approximately 17 per cent of installed capacity in both countries. The RoK also maintains a considerable hydropower capacity, but hydropower plays a comparatively minor role in electricity generation, accounting for approximately 1 per cent of annual generation in 2020. The installed hydropower capacity of Mongolia is less than 2 per cent of the total installed capacity of the country and its contribution to annual electricity generation is minor.

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

Table 1. **Overview of Eastern 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)*
China	1,411	100	N/A	2,200,000	7,623,600	370,160	1,355,200
DPRK	26	N/A	N/A	8,192	23,854	4,790	11,000
Japan	13	100	N/A	293,897	970,770	50,033	86,314
Mongolia	3	N/A	N/A	1,488	7,135	26	83
RoK	52	100	N/A	133,392	552,160	6,506	7,148
Total	-	-	-	**2,636,969**	-	**431,515**	-

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 Eastern Asia varies across countries. In China, SHP refers to hydropower plants with capacities up to 50 MW, with a further subdivision into mini-hydropower (between 100 kW and 2 MW) and micro-hydropower (up to 100 kW). Plants up to 10 MW are considered small-scale in Mongolia and Japan, although no formal definition of SHP exists in either country. In the RoK, SHP is defined as hydropower plants with a capacity of up to 5 MW. No known official definition of SHP exists in the DPRK.

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

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

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed capacity (<10 MW)*	*Potential capacity (<10 MW)*
China	Up to 50 MW	81,300.0	128,000.0	41,985.0	63,500.0
DPRK	N/A	N/A	N/A	522.1	522.1*
Japan	Up to 10 MW	3,577.0	10,330.0	3,577.0	10,330.0
Mongolia	Up to 10 MW	4.7	129.5	4.7	129.5
RoK	Up to 5 MW	N/A	N/A	199.5	1,500.0
Total	-	-	-	**46,288.3**	**75,981.6**

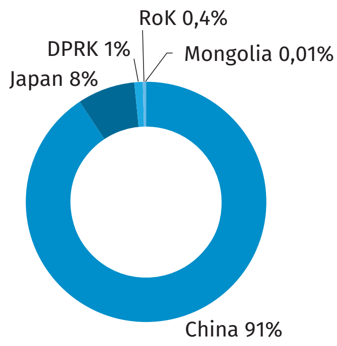
Source: *WSHPDR 2022*[1]

Note: *Based on installed capacity.

In the countries of Eastern Asia, installed capacity for SHP up to 10 MW stands at 46,288.3 MW, or approximately 11 per cent of the total hydropower capacity of the region, while the potential capacity is estimated at 75,981.6 MW. The capacity of SHP up to 10 MW has increased by 1 per cent relative to the *World Small Hydropower Report (WSHPDR) 2019*, mainly due to a re-evaluation of the total installed capacities of the DPRK based on newly available data, as well as increases in the installed capacity of Japan and the RoK. The potential capacity of SHP up to 10 MW in the region has also increased by approximately 1 per cent as a consequence of the re-evaluation of the SHP potentials of the DPRK and Mongolia. Most of the growth in regional SHP capacity over the last decade has been accounted for by the SHP sector of China, although a direct comparison to the dynamics of SHP development in Japan and the RoK is difficult due to differing definitions of SHP. At the same time, the most prospective locations for SHP in China, under both the 50 MW and the 10 MW definition of SHP, have already been developed, while the SHP potential of Japan, the RoK and Mongolia remains largely untapped. No reliable estimate of undeveloped SHP potential in the DPRK is available, but circumstantial evidence suggests the country retains significant untapped hydropower resources.

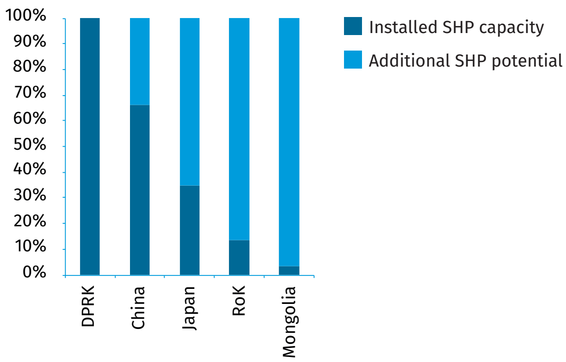
The national share of regional installed capacity for SHP up to 10 MW by country is displayed in Figure 1, while the share of total national SHP potential utilized by the countries in the region is displayed in Figure 2.

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



Source: *WSHPDR* 2022[1]

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



Source: *WSHPDR 2022*[1]

Note: For SHP up to 10 MW in the case of the DPRK, Japan, RoK and Mongolia. In the case of China, the up to 50 MW definition is used in order to reflect the latest data on domestic SHP development.

In **China**, SHP is a mature technology and is widely adopted all over the country, with 43,957 SHP plants up to 50 MW in operation as of 2020. China has added approximately 2,000 MW of SHP up to 50 MW since the publication of the *WSHPDR 2019*. As of 2020, the installed capacity for SHP up to 50 MW in China was approximately 81,300 MW and potential capacity is estimated at 128,000 MW, indicating that nearly 64 per cent of SHP potential up to 50 MW has been developed. For SHP up to 10 MW, the installed capacity was 41,985 MW as of 2020 while potential capacity is estimated at 63,500 MW, indicating that approximately 66 per cent of the potential for SHP up to 10 MW has been developed. China has set ambitious targets for hydropower development, including building an additional 70,000 MW of hydropower capacity by 2030 and another 70,000 MW by 2050, with SHP intended to account for a share of this additional capacity. Responsibility for SHP development in the country has gradually been shifting towards the private sector.

The estimated total installed capacity of SHP up to 10 MW in the **DPRK** is 522.1 MW. Of this total, 470.9 MW is accounted for by plants constructed prior to 2005, while the remaining 51.2 MW was added between 2016 and 2019. In 2015, the construction of new hydropower projects was announced at six different sites, but no specific data on the potential SHP capacity or current status of these projects are available. Likewise, there is no reliable estimate of the existing SHP potential in the country beyond that which has already been developed. Circumstantial evidence including the topography and hydrological conditions of the DPRK suggest that untapped hydropower potential in the country is considerable. Additionally, many of the previously installed SHP plants, particularly those in the micro- and mini-hydropower capacity range, may no longer be operational or are in need of extensive refurbishment.

In **Japan**, the total installed capacity of SHP under 10 MW is 3,577 MW, while potential capacity is estimated at 10,330 MW, indicating that approximately 35 per cent of the SHP potential in the country has been developed. Japan has a long history of hydropower development, but opportunities for construction of additional large-scale hydropower plants are limited.

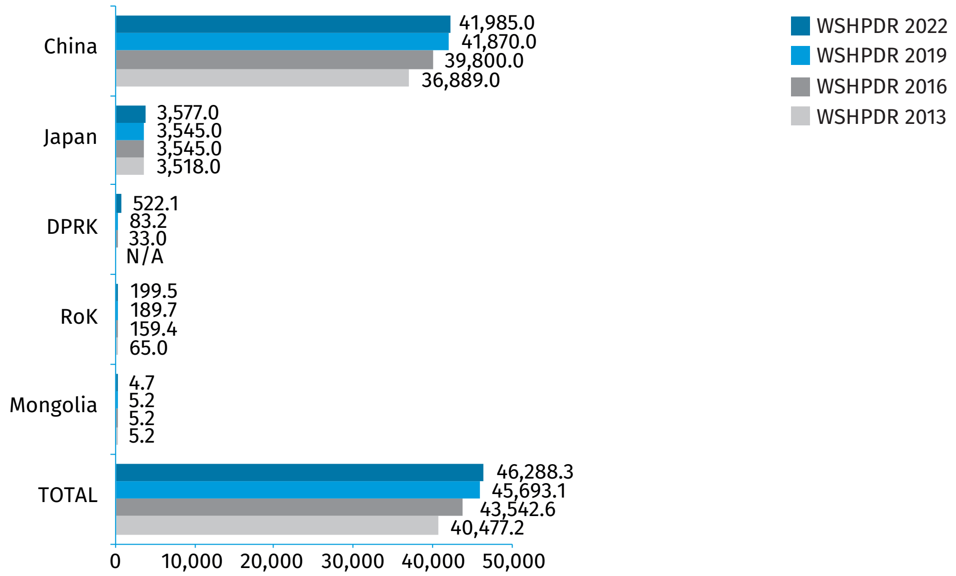
Consequently, construction of SHP plants represents the most active subsector of hydropower development in the country and is promoted by national government policy as well as by non-governmental organizations, agricultural cooperatives and other local organizations.

Mongolia has 10 SHP plants up to 10 MW with a total installed capacity of 4.7 MW. The potential capacity of SHP up to 10 MW in Mongolia is estimated at 129.5 MW, indicating that approximately 3 per cent has been developed. However, five of the existing SHP plants require major restoration work and are currently out of operation, while the other five only operate during the summer. Consequently, SHP in Mongolia is considered a seasonal energy source.

The **RoK** currently has 169 operating plants up to 10 MW with a combined installed capacity of 199.5 MW. Potential capacity for plants up to 10 MW in the RoK is estimated at 1,500 MW, indicating that over 10 per cent has been developed. The SHP sector in the country is undergoing active development, with 14 new plants commissioned in 2018–2019. Ongoing projects include several SHP plants being constructed as auxiliary facilities at the sites of existing thermal power plants.

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

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



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

Note: For China, the up to 50 MW definition of SHP is used.

Climate Change and Small Hydropower

Glaciers feeding the two river basins in the Eastern Asia region with the highest degree of hydropower development (the Yellow River and Yangtze River basins) have experienced significant melting with increased temperatures. However, the direction of future changes in precipitation is unclear. In the Yellow River basin, other human economic activities, such as agriculture, have a significantly higher impact on the seasonal changes and streamflow reduction than climate change. Analysis of existing hydropower projects on the Yalong River suggests that modified reservoir operations could help manage the expected future variability in streamflow. Rivers in Mongolia appear to be more sensitive to small changes in temperature and precipitation, affecting generation from hydropower. An example is the Uvurkhangai SHP plant which was abandoned due to insufficient water levels. In Japan, heavy rainfall and suspended sediment in rivers are both projected to increase by up to 25 per cent by 2100, which is expected to increase the operation and maintenance costs of SHP plants.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

One of the greatest barriers to SHP development in **China** are regional development disparities. While nationally, the rate of utilization of existing SHP potential stands at 64 per cent, many provinces in the eastern part of the country have reached a rate of 80 per cent. As the number of available sites for SHP projects decreases, new projects encounter increasing difficulties in terms of land compensation, labour cost, environmental impacts and issues pertaining to resettlement of people in affected areas. Other issues include the overexploitation of the natural environment as a consequence of previous projects and the aging of SHP facilities. Measures adopted to support SHP development in the country have included subsidization of construction and rehabilitation of SHP projects in rural areas, ecological restoration in overexploited regions and improvement of the legal and regulatory system for rural hydropower, among others.

Barriers to SHP development in the **DPRK** include a lack of accurate data on SHP potential, insufficient government funds and international financing options, extreme weather events, aging infrastructure and a lack of domestic capacity to produce generation and automation equipment. At the same time, topographical data suggest that much of the SHP potential in the DPRK remains untapped and many old SHP plants constructed in previous decades can be renovated and rebuilt to meet modern standards.

Barriers to SHP development in **Japan** include insufficient human resources for implementing SHP projects, difficulties with building a wholesale electricity market as well as with researching and developing community grids, lack of clarity on the practicalities of market liberalization and recent legislative focus on the development of wind and solar power. The implementation of SHP projects is additionally complicated by the community-based nature of typical SHP projects, which requires extensive engagement and consultation with local communities. Conditions conducive to SHP development include abundant remaining hydropower potential, extensive local experience and expertise in SHP as well as established financial support schemes.

Today, **Mongolia** faces several problems in developing its SHP potential, which include the lack of specific regulations and legislation, severe winter weather, low feed-in tariffs (FITs), a lack of human resources as well as political and social concerns regarding hydropower development in general. At the same time, the Government of Mongolia has signalled its intention to adopt legislation favourable for SHP development including more attractive FITs. Government agencies have also stepped in to help facilitate private investment in hydropower projects.

Barriers to SHP development in the **RoK** include limited water resources, insufficient development of local technology, dependence on foreign companies in the SHP sector, complaints from environmental groups and local residents, and high initial investment cost for SHP projects. Enabling factors include government support for new and renewable energy projects, abundant untapped SHP undeveloped potential and a broad range of tools to facilitate and attract investment in the SHP sector.

REFERENCES

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

China

Lina BAO, International Center on Small Hydro Power (ICSHP)

KEY FACTS

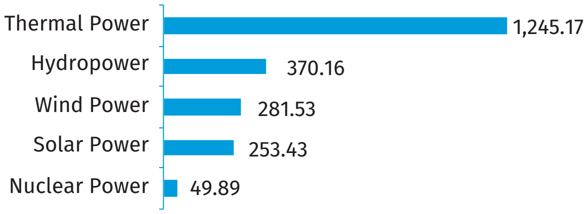
Population	1,410,929,360 (2020)[1]
Area	9,600,000 km^2 [2]
Topography	China is roughly divided into two parts: lowlands in the east, which account for approximately 20 per cent of the total territory, and mountains and plateaus in the west, which constitute the remaining 80 per cent of the country's territory. The highest mountain in China, as well as in the world, is Mount Everest, situated in the Himalayas in the Tibet Autonomous Region, on the border with Nepal. Its summit is 8,848 metres above sea level. The lowest point in China is Ayding Lake, located in Xinjiang Uyghur Autonomous Region, situated at 154 metres below sea level.[2]
Climate	Climate in China is extremely diverse, ranging from tropical in the south to subarctic in the north. Eastern China has subtropical monsoon, temperate monsoon and tropical monsoon climates, whereas north-western China has a temperate continental climate and the Qinghai-Tibet Plateau has an alpine climate. The climate of China is significantly impacted by monsoons, with humid, hot summers and dry, cold winters. The prevailing northerly wind in winter occurs in the inland. It is cold and dry in nature, so there is generally less precipitation and temperatures are lower, especially in the north. The summer monsoon comes from the south-east (Pacific Ocean) and the south-west (Indian Ocean). It is warm and humid and generally leads to a precipitation increase. Minimum temperatures in winter (December–February) range from -27 °C in northern Manchuria to -1 °C in the North China Plain and southern Manchuria, to 4 °C along the middle and lower valleys of the Yangtze River and to 16 °C farther south. Summer temperatures in southern and central China average approximately 27 °C in July. Northern China has a shorter summer season and much cooler nights.[2]
Climate Change	Between 1901 and 2010, the average temperature in mainland China increased by 0.98 °C. While annual average precipitation did not show any statistically significant changes between 1960 and 2010, spring and autumn precipitation declined and summer precipitation increased. Under PCP8.5, temperatures are projected to increase by 4.3 °C in the south-west of the country and by 5.5 °C in the north-west. Under most scenarios, further increases in precipitation across the country are most likely.[3,4]
Rain Pattern	Given its vastness, many degrees of latitude and complex terrain, China has a variety of precipitation levels, including continental monsoon areas. Annual mean rainfall varies from 0 mm in desert regions to 1,500 mm on the east coast, with precipitation levels usually peaking in the summer months between June and August.
Hydrology	There are over 1,500 rivers, each with a drainage area of over 1,000 km^2. The great rivers of China generally flow from west to east, flowing out into the Pacific Ocean. The largest river in China, the Yangtze, is approximately 5,525 kilometres in length and drains an area of approximately 1.8 million km^2. The main river in northern China and the second largest in the country is the Yellow River, approximately 4,671 kilometres in length. The valley of the Yellow River covers an area of 1.5 million km^2.[2]

ELECTRICITY SECTOR OVERVIEW

By the end of 2020, total installed capacity in China had reached approximately 2,200 GW. This consisted of 1,245.17 GW of thermal power (almost 57 per cent), 370.16 GW of hydropower (17 per cent), 281.53 GW of wind power (13 per cent), 253.43 GW of grid-connected solar power (12 per cent) and 49.89 GW of nuclear power (2 per cent) (Figure 1).[5] China has the largest installed capacity of hydropower in the world.

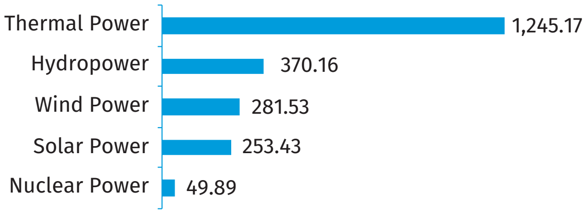
In 2020, electricity generation in China totalled 7,623.6 TWh. Hydropower generation, at 1,355.2 TWh, accounted for 18 per cent of the total generation. Renewable energy generation amounted to 2,082.8 TWh (27 per cent) (Figure 2).[6] Hydropower is still the main source of renewable energy in China, accounting for 65 per cent of total renewable energy generation in 2020.[6]

Figure 1. **Installed Electricity Capacity by Source in China in 2020 (GW)**



Source: NEA[5]

Figure 2. **Annual Electricity Generation by Source in China in 2020 (TWh)**



Source: CEC[6]

China has two grid operating companies, the State Grid Corporation and the South China Grid Corporation. The national grid is divided into six parts. The North-Eastern China Grid, Northern China Grid, Eastern China Grid, Central China Grid, and North-Western China Grid are managed by the State Grid Corporation, while the Southern China Grid is managed by the South China Grid Corporation. Provincial and municipal grid utilities are typically the sole buyers of power from generators and they resell to customers and distribution companies in their service areas.

The National Development and Reform Commission (NDRC) and the State Electricity Regulatory Commission (SERC) share the responsibility for the regulation of the power sector of China. The NDRC's responsibilities include investment, pricing and power plant approval, while the SERC is responsible for the design and oversight of generation markets and implementation of power sector reforms. The SERC also provides advice to the NDRC on pricing and market reforms.[7]

In July 2012, China adopted a Multistep Electricity Price Mechanism, which increased the consumer tariff in multiple steps as the consumption level rose. Peak and off-peak tariffs were also implemented. Consumer tariffs vary across provinces. In 2021, the average tariff for household consumers was 0.542 CNY/kWh (USD 0.085) and the average industrial tariff was 0.635 CNY/kWh (0.100 USD/kWh).[8]

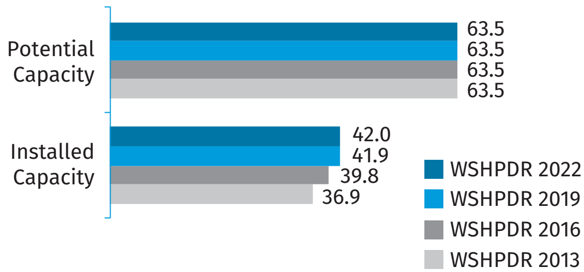
SMALL HYDROPOWER SECTOR OVERVIEW

In China, small hydropower (SHP) refers to capacities of up to 50 MW, with a further classification into mini-hydropower (up to 2 MW) and micro-hydropower (up to 100 kW).

Hydropower in China is a mature technology and SHP is widely used across the country, with plants present in more than 1,700 counties and over 30 provinces, regions and municipalities. China has a unique management system for SHP. Projects in the east connect to the grid directly, while projects in the central and western regions form local grids or isolated mini-grids with their own supply areas.

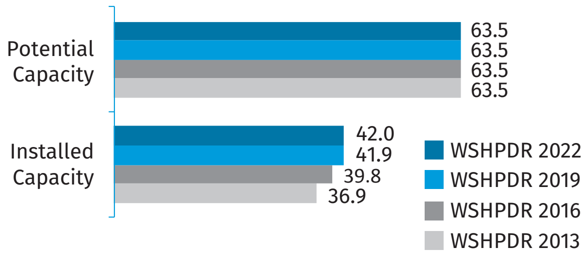
In 2020, there was a total of 43,957 SHP plants up to 50 MW in operation in China, with a total installed capacity of 81,338.28 MW and an annual power generation of approximately 242 TWh.[9] Total potential capacity for SHP up to 50 MW is estimated at 128 GW, indicating that almost 64 per cent of available potential has already been developed. Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, potential capacity for SHP up to 50 MW has remained unchanged, whereas the installed capacity increased by approximately 3 per cent due to the commissioning of new plants (Figure 3). For SHP up to 10 MW, the total installed capacity was 41,985 MW as of 2020, and annual power generation in 2020 amounted to approximately 112 TWh. Potential capacity for SHP up to 10 MW is estimated at 63.5 GW, indicating that 66 per cent has been developed.[10] Relative to the *WSHPDR 2019*, the installed capacity of SHP up to 10 MW increased by less than 1 per cent due to the commissioning of new plants, while the estimated potential capacity has remained unchanged (Figure 4).

Figure 3. **Small Hydropower Capacities up to 50 MW in the WSHPDR 2013/2016/2019/2022 in China (GW)**



Source: MWR,[9] *WSHPDR 2013*,[11] *WSHPDR 2016*,[12] *WSHPDR 2019*[13]

Figure 4. **Small Hydropower Capacities up to 10 MW in the WSHPDR 2013/2016/2019/2022 in China (GW)**



Source: ICSHP,[10] *WSHPDR 2013*,[11] *WSHPDR 2016*,[12] *WSHPDR 2019*[13]

In 2020, 69 new SHP plants with a combined capacity of 804.66 MW were put into operation in rural areas of China. Of the newly commissioned plants, almost 67 per cent were within the 10–50 MW capacity range and the remaining 33 per cent were of up to 10 MW capacity. The newly installed capacity is mainly concentrated in the south-west of the country. The total investment cost of these projects equalled CNY 5.86 billion (USD 0.92 billion).[9]

The Government of China has always attached great importance to SHP development, actively supporting and promoting the construction of new power plants for rural electrification and as a green energy replacement for fossil fuel sources. SHP projects have made important contributions to the promotion of river governance, ecological improvements, environmental protection and local social and economic development. At the same time, it should be noted that there are still many weak spots in the planning, design, construction, operation and management of SHP plants in some areas and incentives and restrictions promoting green development of SHP need to be further established. In particular, to ensure the development of green SHP, it is critical to actively adjust to climate change and realize the upgrading of plant quality and efficiency.

RENEWABLE ENERGY POLICY

The Energy Development Strategy Action Plan 2014–2020, launched on 19 November 2014 by the State Council, aims to: (a) increase the share of non-fossil fuel sources in total energy consumption to 15 per cent; (b) reduce the share of coal to less than 62 per cent and (c) reach a more than 10 per cent share of natural gas in the total primary energy mix by 2020.[14] Specific measures include optimizing industrial and energy structures, adjusting the fossil fuel energy structure, further developing hydropower, safely developing nuclear power, actively developing wind power, promoting multipurpose utilization of solar energy and developing biomass energy, along with other renewable energy sources.

The country's target for hydropower development, including SHP, was set to increasing the capacity to 350 GW by 2020 (which was achieved on time), with an additional capacity of 70 GW by 2030 and another 70 GW by 2050. This will bring the total hydropower installed capacity to 490 GW.[15]

The targets for wind energy development are to achieve installed capacities of 200 GW, 400 GW and 1,000 GW by 2020, 2030 and 2050, respectively, and to meet 17 per cent of the total electricity demand in the country through wind power by 2050.[16] The national solar energy utilization target is for solar energy to replace 150 million tons, 310 million tons and 860 million tons of coal and generate approximately 150 TWh, 510 TWh and 2,100 TWh of electricity by 2020, 2030 and 2050, respectively.[17]

The Renewable Energy Law of the People's Republic of China aims to promote the development and utilization of renewable energy, increase energy supply, improve energy efficiency, ensure energy security, protect the environment and achieve sustainable economic and social development goals.[18]

Prices for electricity generated by on-grid plants powered by renewable energy sources are to be determined by the administrative department of price of the State Council according to the renewable energy technology, the regional conditions, the principles of promoting the development and utilization of renewable energy and economic rationality. The prices for each technology should be adjusted in time.[18]

Renewable energy projects are granted financial subsidies under the National Renewable Energy Industry Development Guidance Catalogue, Renewable Energy Industry Development Guidance Catalogue and Renewable Energy Development Conditions. The state grants preferential taxation to projects listed in the Renewable Energy Industry Development Guidance Catalogue.[18]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

The Government of China has passed a series of policies to support and encourage local governments and local people to develop SHP resources. These policies include: Self-Construction, Self-Management and Self-Consumption; Electricity Generates Electricity; Small Hydropower Should Have Its Own Supply Area; Small Hydropower Has Priority to Dispatch; Fully Absorb by Grid; and Same Grid Same Tariff. A value-added tax (VAT) for SHP has stood at 6 per cent since 1994, making it much more favourable than the 17 per cent tax levied on large hydropower plants. The Bureau of Hydropower and Rural Electrification Development is also working to promulgate a specialized regulation on rural hydropower development and management.

The Thirteenth Five-Year Plan (2016–2020) set an explicit target to increase SHP capacity by 10 GW. This included 7 GW from the Rural Electrification Programme, the SHP Replacing Firewood Programme and the Refurbishment and Upgrading Programme (for plants built before 2000) and another 3 GW from social investment.[19] At the moment of writing of the present chapter, the Fourteenth Five-Year Plan was being developed.

In 2019, the Ministry of Water Resources and the Ministry of Finance jointly issued the Fourteenth Five-Year Plan for Rural Hydropower Efficiency Expansion and Reconstruction Performance Management Measures, which aims to guide provinces in entrusting third-party agencies to carry out performance evaluations for hydropower projects and to put forward clear requirements for various tasks.

There is no unified feed-in tariff (FIT) for SHP in China. Each province has the right to establish a benchmark price for SHP projects on its territory. These prices are based on the average purchasing price of the provincial electricity grid company as well as the consideration of the supply and demand trends of the electricity market and SHP development costs. In 2017, the average FIT for SHP plants up to 50 MW connected to national grids and local grids was between 0.316 CNY/kWh (0.05 USD/kWh) and 0.252 CNY/kWh (0.04 USD/kWh).[20]

On 6 February 2016, the Ministry of Finance and the Ministry of Water Resources jointly issued the official document Financial Construction (2016) No.27 regarding the extension of the implementation of the SHP Capacity Expansion and Efficiency Improvements Programme. This national SHP refurbishment programme follows the principle of “focus on nature restoration, complemented by artificial modification”. The document set the requirements for ecological flow and ecological restoration downstream of SHP plants for the purpose of ecological river recovery at SHP locations. The required measures to ensure green SHP include the following:

- SHP plants should install eco-hydroturbines or other ecological flow discharge facilities to meet the river ecology requirement;
- SHP plants should be equipped with an ecological flow discharge monitoring system or a joint operation system for cascade plants;
- If difficulties with ensuring natural recovery of river ecology after the installation of ecological flow discharge facilities persist, the SHP plant can adopt such measures as connectivity and habitat restoration.[21]

Moreover, a set of technical standard systems, including an SHP programme encompassing design, construction, installation, testing, operation and equipment manufacturing, was established to provide technical support and services for SHP development.

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

In July 2011, the Ministry of Finance and the Ministry of Water Resources jointly issued the Interim Measures for the Management of Financial Subsidy Funds for Rural Hydropower Efficiency Expansion and Reconstruction. Through this document, the Government of China allocated financial resources from a dedicated fund for renewable energy development to support measures aimed at improved efficiency, capacity expansion and renovation for rural hydropower. The Government provides fixed subsidies for efficiency enhancement and capacity expansion projects based on the installed capacity after the transformation. The subsidy standard is: 700 CNY/kW (110 USD/kW) in the eastern region, 1,000 CNY/kW (158 USD/kW) in the central region and 1,300 CNY/kW (205 USD/kW) in the western region. The state subsidy funds for a single project shall not exceed 50 per cent of the total investment in the project’s efficiency enhancement and capacity expansion.[22]

In addition to investments made by the Government, many private investors have become increasingly involved in hydropower development in the country. Between 1990 and 2000, SHP investment experienced a gradual transition away from central and local government sources, shifting towards corporate enterprises, including foreign ones, with joint ventures and private hydropower plants accounting for an increasing proportion of the newly installed capacity. Projects in which local governments are the investors are more focused on social and public welfare, whilst projects where communities or private entities are the investors are more profit-oriented.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

In the case of China, climate change can have both positive and negative impacts on the hydropower sector. For example, on the one hand, the increase in temperature in spring will reduce the utilization hours of power plants, while, on the other hand, the increase in temperatures and precipitation in winter will increase utilization hours. SHP generation also remains vulnerable to such climate change-induced factors as changes in precipitation, temperature drop and increased frequency and intensity of droughts.[23,24]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The key factors hindering SHP development in China include the following:

- It is becoming increasingly difficult to develop the remaining SHP potential due to development disparities across regions. For example, although SHP development has reached 64 per cent of the total potential (SHP up to 50 MW) nationwide, it is actually much higher in some eastern provinces, with some areas reaching a development rate of 80 per cent. Aside from technical difficulties, constraints caused by land compensation, labour cost, environmental and resettlement issues should also be taken into consideration.
- For some rivers, the environment has been damaged by projects that did not strictly implement measures for soil and water conservation and environmental protection. Some rivers were overexploited and some sections dehydrated, affecting the availability of drinking water downstream and the ecology of the whole river.
- The allocation of hydropower resources in some river basins is unreasonable due to past limitations in technology, funding and layout. Some medium and small rivers lack a combined dispatching system.
- Some of the existing plants are already ageing and in a state of disrepair.[25]

The Government of China has implemented various measures to support SHP in the country, particularly focusing on the sustainable development of the technology, including the following:

- Provision of subsidies for the construction and rehabilitation of SHP projects in rural areas, particularly low-income communities;
- Conduct of efficiency enhancement and capacity expansion programmes for rural SHP;

- Ecological restoration of water courses affected by SHP;
- Improvement of the legal and regulatory system for rural hydropower;
- Establishment of a multi-sectoral joint supervision mechanism;
- Conduct of large-scale unannounced investigations and inspections;
- Construction management and social supervision systems.

Further development of the remaining SHP potential in China requires promoting local legislation, strengthening supervision of SHP development and operation as well as strengthening social supervision and resource management. Furthermore, it is necessary to steadily increase the investment in rural SHP projects and ensure the support of SHP development through the national fiscal and tax policy. Finally, new mechanisms for the participation of farmers in SHP development, as a long-term stable source of income, can be explored.[26]

REFERENCES

1. World Bank (2020). *World Development Indicators. Population, total - China.* Available at https://data.worldbank.org/indicator/SP.POP.TOTL?locations=CN (Accessed 17 January 2022).
2. Nations Encyclopedia (n. d.). *Asia and Oceania, China*. Available at http://www.nationsencyclopedia.com/Asia-and-Oceania/China.html (Accessed 17 January 2022).
3. Climate Change Knowledge Portal (n.d.). *China: Climate Projections.* Available at https://climateknowledgeportal.worldbank.org/country/china/climate-data-projections (Accessed 17 January 2022).
4. Climate Change Knowledge Portal (n.d.). *China: Current Climate.* Available at https://climateknowledgeportal.worldbank.org/country/china/climate-data-projections (Accessed 17 January 2022).
5. National Energy Administration (2020). *National Power Industry Statistics Data.* Available at http://www.nea.gov.cn/2021-01/20/c_139683739.htm [in Chinese] (Accessed 17 January 2022).
6. China Electricity Council (CEC) (n.d.). *Official website* Available at https://www.cec.org.cn/detail/index.html?3-292820 (Accessed 17 January 2022).
7. The Regulatory Assistance Project (2008). *China's Power sector: A Backgrounder for International Regulators and Policy Advisors.* Available at https://www.raponline.org/wp-content/uploads/2016/05/rap-chinapowersectorbackground-2008-02.pdf (Accessed 17 January 2022).
8. REUTERS (2021). *China signals likely rise in household electricity prices*. Available at https://www.reuters.com/world/china/china-signals-likely-rise-household-electricity-prices-2021-07-01/ (Accessed 17 January 2022).
9. Ministry of Water Resources (MWR) (2020). *Rural Hydropower Bulletin 2020*. [not available online]
10. International Center on Small Hydro Power (ICSHP) (2020). Internal ICHSP data.
11. UNIDO, ICSHP (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
12. UNIDO, ICSHP (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
13. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019.* United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
14. State Council of China (2014*). The Energy Development Strategy Action Plan 2014-2020.* Available at http://www.gov.cn/zhengce/content/2014-11/19/content_9222.htm [in Chinese] (Accessed 17 January 2022).
15. China Reform Daily (2015). *China's Hydropower Opens Sustainable Development in the New Century.* Available at http://www.cec.org.cn/yaowenkuaidi/2015-05-29/138470.html.
16. International Energy Agency (IEA) & Energy Research Institute (2012). *Technology Roadmap: China Wind Energy Development Roadmap 2050.* Available at https://www.china.tu-berlin.de/fileadmin/fg57/SS_2012/Umwelt/IEAchina_wind_2050.pdf (Accessed 17 January 2022).
17. China Renewable Energy Center (2014). China Renewable Energy Road Map 2050. 25 December 2014. Available at www.cnrec.org.cn/cbw/zh/2014-12-25-456.html.
18. President of the People's Republic of China (2005). *Order of President of the People's Republic of China No. 33. Renewable Energy Law of the People's Republic of China.* Available at http://english.mofcom.gov.cn/article/policyrelease/Businessregulations/201312/20131200432160.shtml (Accessed 17 January 2022).
19. Tian, Zh. (2015). *Statement to the Ministry of Water Resources and Hydropower Bureau*. Rural Hydropower Conference. Available at http://www.shp.com.cn/ldjh/sdjldjh/201504/t20150420_630498.html.
20. Ministry of Water Resources, Rural Hydropower and Electrification Bureau (2018). *The 2017 Rural Hydropower Statistics Yearbook*. [not available online]
21. Ministry of Finance & Ministry of Water Resources (2016). *Notice on Continuing the Implementation of Rural Hydropower Efficiency Improvement and Capacity Expansion (2016) No. 27*. Available at http://nssd.mwr.gov.cn/zdgz/ncsd/201901/t20190115_1099716.html [in Chinese] (Accessed 17 January 2022).
22. Ministry of Finance & Ministry of Water Resources (2011). *Notice on Issuing Interim Measures for the Management of Financial Subsidy Funds for Rural Hydropower Efficiency Expansion and Reconstruction (2011) No. 504.* Available at http://www.cnki.com.cn/Article/CJFDTotal-XSDI201105003.htm [in Chinese] (Accessed 17 January 2022).
23. Li, L. (2020). *Climate Change Impact on Hydropower Production and Market. Literature Review and Case Study of Hydropower in China with Changing Climates*. China-Arab States Science and Technology Forum, 07, 204-207.

Available at https://kns.cnki.net/kcms/detail/detail.aspx?dbcode=CJFD&dbname=CJFDLAST2020&filename=ZAKJ202007056&v=2nTp05hVBkCnEu7zeA%25mmd2F4RRCyfB3oyIdrpW7b5reKrxo6JaJPiSbqOqWtccq4FdSQ [in Chinese] (Accessed 17 January 2022).
24. Cui, G. (2008). Impact and Counter-strategy of Climate Change on Local Hydropower in Changbai Mountainous Area. *China Water Power & Electrification*, 12, 36-39,42. Available at https://d.wanfangdata.com.cn/periodical/dfdlgl200812010 [in Chinese] (Accessed 17 January 2022).
25. Zhou, X. (2015). *Rural Hydropower Conference. Statement to the Ministry of Water Resources.* 9 April 2015. Available at http://www.shp.com.cn/ldjh/bldjh/201504/t20150420_630501. html.
26. Zhang, L. (2010). Small hydropower will give full play to its great energy-a report from the first "China Small Hydropower Forum". *China Economic Herald*, 05. Available at http://www.ceh.com.cn/epaper/search/mydetail.jsp?searchKeys=%D0%A1%CB%AE%B5%E7%BD%AB%B7%A2%BB%D3%B4%F3%C4%DC%C1%BF&newsID=74893&fieldsSelected=&StartDate=&EndDate=&orderKey=&pagename=null&papername=%D6%D0%B9%FA%BE%AD%BC%C3%B5%BC%B1%A8 [in Chinese] (Accessed 17 January 2022).

Democratic People's Republic of Korea

International Center on Small Hydro Power (ICSHP)

KEY FACTS

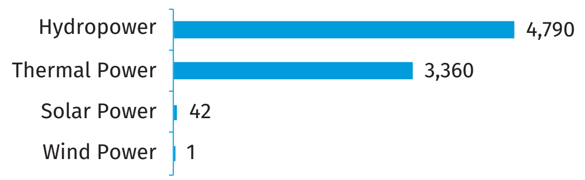
Population	25,778,815 (est. 2020)[1]
Area	120,540 km^2 [1]
Topography	Approximately 80 per cent of the territory of the Democratic People's Republic of Korea (DPRK) is mountainous and rugged.[2] The north and east of the country are composed mainly of high mountains and there are some small plains along the southern and western coastlines.[3] The largest ones are the Pyongyang and Chaeryng Plains, each covering approximately 500 km^2.[4] The highest point is Mount Paektu at 2,744 metres.[5]
Climate	The DPRK is located in the northern part of the Korean Peninsula and the climate of the country is influenced by the Asian continental landmass as well as by oceans to its east and west. The DPRK has a mild temperate climate with four distinct seasons. Summers (from June to August) are hot and humid, with average temperatures of 24 °C, while the spring and winter are dry and cold, with temperatures in the winter (from November to February) averaging -5.5 °C. The annual average temperature is 9–10 °C.[2] In the capital, Pyongyang, daily average minimum and maximum temperatures are -13 °C and -3 °C in January and 20 °C and 29 °C in August.[6]
Climate Change	Observed climate change on the territory of the DPRK has included a rise in winter and spring temperatures of 4.9 °C and 2.4 °C, respectively, between 1918 and 2000. Climate change models predict an increase in summer maximum temperatures of 1.04–6.84 °C by 2100 relative to the 1960–1990 baseline period, depending on the severity of the scenario.[2]
Rain Pattern	Annual precipitation in the DPRK ranges from 810 mm to 1,520 mm and average annual precipitation is 1,054 mm. More than 60 per cent of all rainfall takes place between June and September.[7]
Hydrology	The Yalu River, also known as the Amnok River and located on the border between the DPRK and China, is the longest river in the country, at 790 kilometres. The Yalu River flows from Mount Paektu and continues in a westerly direction into the Yellow Sea. The second longest river in the country is the Tumen River, at 521 kilometres, also begins at Mount Paektu, passing through the DPRK border with Russia and China before draining into the Sea of Japan. The Taedong River is the third longest at 397 kilometres. It originates in the Rangrim Mountains and also drains into the Yellow Sea. Natural lakes in the DPRK are usually small and there are approximately 1,000 artificial lakes, most of which were formed as part of irrigation and hydropower construction projects.[3,4,8]

ELECTRICITY SECTOR OVERVIEW

The net installed capacity of electricity plants in the Democratic People's Republic of Korea (DPRK) was estimated at 8,192 MW in 2020, including 4,790 MW (58 per cent) provided by hydropower, 3,360 MW (41 per cent) provided by thermal power, 42 MW (1 per cent) provided by solar power and approximately 1 MW (less than 1 per cent) provided by wind power (Figure 1).[9,10]

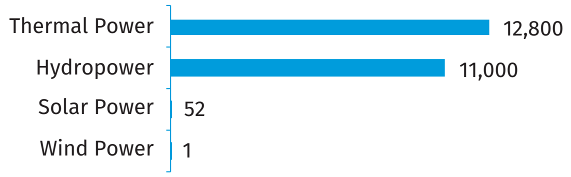
Electricity generation was estimated at 23,854 GWh in 2019. Approximately 12,800 GWh (54 per cent) was generated by thermal power plants and another 11,000 GWh (46 per cent) was generated by hydropower plants, while the remaining 53 GWh (less than 1 per cent) was accounted for by solar power and wind power (Figure 2).[10] Off-grid solar power in the DPRK has expanded considerably in recent years, with approximately 55 per cent of households equipped with solar panels in 2019, but still accounts for a tiny fraction of total electricity generation in the country.[11]

Figure 1. **Installed Electricity Capacity by Source in the Democratic People's Republic of Korea in 2020 (MW)**



Source: IRENA[10]

Figure 2. **Annual Electricity Generation by Source in the Democratic People's Republic of Korea in 2019 (GWh)**



Source: IRENA[10]

Electricity generation in the DPRK has been affected by climate change and the sanctions of the United Nations Security Council. Climate change has led to severe weather conditions, with droughts, floods or both occurring yearly since 2014. At the end of August 2016, there was an extensive rainfall in the province of North Hamyong, causing the Tumen River to flood.[12] Between January and July of 2017, there was a 30–80 per cent decrease in rainfall (compared to the average).[13] In the past, this type of severe weather affected hydropower plants negatively, rendering them inoperable.[14,15] In addition to this, the sanctions imposed by the Security Council have made it difficult for the country to trade and in particular to import oil, a resource that is not available domestically, which has in turn adversely affected all economic activities in the country.[16]

The supply of electricity in the DPRK consistently falls short of electricity demand.[17] Many areas outside of Pyongyang receive a modest amount of power and power outages are a regular occurrence throughout the country.[18] Electricity rationing is also common. For example, in rural areas electricity is only available for a few hours per day.[19]

Estimates of electricity access in the DPRK range anywhere from 26 per cent to over 50 per cent. While most of the population has at least some access to electricity, daily availability may be limited to as little as a few hours or none at all.[11,20,21]

The United Nations Development Programme (UNDP) carried out the Sustainable Energy Solutions for Rural Livelihoods in the DPRK project between 2015 and 2019, among other targets, aiming to improve rural electricity access for individual rural households, promote energy saving technology and develop local technical capacity in electricity generation from renewable energy sources. The project involved the installation of hundreds of solar photovoltaic (PV) systems and energy-efficient technologies at the community and household level and resulted in an estimated electricity savings of 2.4 GWh/year in the agricultural sector.[22] There have also been multiple Global Environmental Fund (GEF) projects in the DPRK, which have helped to increase the electrification rate in rural areas of the country, including the Project on Small Wind Energy Development and Promotion in Rural Areas (SWEDPRA).[23]

The electricity infrastructure of the country is outdated, inefficient and in need of refurbishment, with some of the generation and transmission equipment dating back several decades. Modernizing the electricity sector has been a priority for the Government of the DPRK; in particular, upgrading generating and transmission capacities to increase efficiency and reduce losses.[24] In 2015, electricity consumed by the energy industry and other losses were estimated at 3,475 GWh. The Government of the DPRK has made a commitment to reducing power transmission and distribution losses by 6 per cent by 2030. In 2017, the Government also announced plans for the construction of the new large-scale Tanchon hydropower plant, which is expected to alleviate the electricity supply problem.[25,26] The Tanchon project continued apace through 2019, but progress had slowed as of 2020.[27]

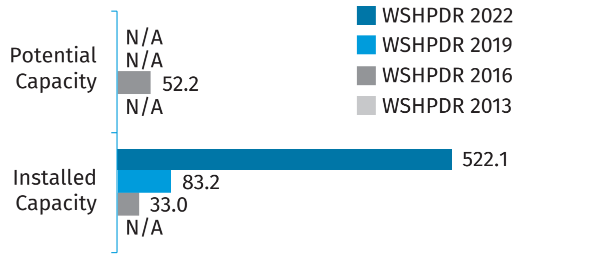
Key ministries involved with the electricity sector include the Ministry of Electric Power Industry, the Ministry of Atomic Energy and the Ministry of Coal Industry. The County People's Committees (CPC) represent the lowest administrative level providing supporting services and facilities to the rural population, including in matters of electricity access.[19] Finally, the Ministry of State Construction Control is responsible for approving construction projects (such as hydropower plants) and their locations.[28]

The electricity tariff system in the DPRK has been undergoing dramatic changes in recent years. Historically, electricity has been provided at the symbolic price of 0.12 KPW/kW (0.000015 USD/kWh) and usage was estimated by house visits from administrative staff. However, with electricity access extremely limited in much of the country in recent decades, black market schemes have in practice often replaced formal payments. In 2017, the Government installed electricity meters in Pyongyang, charging a rate of 35 KPW/kW (0.004375 USD/kWh). Since 2020, an additional experimental measure requires households in Pyongyang with above-average electricity use to pay a rate of 50 USD/month, with a six-month advance payment requirement.[29,30]

SMALL HYDROPOWER SECTOR OVERVIEW

For the purposes of this chapter, small hydropower (SHP) is defined as hydropower plants with a capacity of 10 MW or less. Challenges in data access for the DPRK mean that reliable figures on SHP capacity are not available, but it is estimated that the total installed capacity of SHP in the country as of 2005 was approximately 470.9 MW.[31] Additional SHP capacities commissioned between 2016 and 2019 have been estimated at 51.2 MW (Table 1).[24,32,33,34] Total installed SHP capacity in the DPRK is thus estimated at 522.1 MW, although it is suspected some of this capacity is not currently operational. Data on SHP potential are not available. Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, installed SHP capacity has increased more than five-fold, due to the inclusion of more comprehensive data on historical SHP construction (Figure 3).

Figure 3. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in the Democratic People's Republic of Korea (MW)**



Source: *WSHPDR 2019*,[24] Yoon,[31] UNFCCC,[33] UNDP DPRK,[34] *WHSPDR 2013*,[35] *WHSPDR 2016*[36]

Table 1. **List of Selected Small Hydropower Plants in the Democratic People's Republic of Korea (MW)**

Name	*Location*	*Capacity (MW)*	*Plant type*
Hamhung No.1	Kumjin River	10.00	Reservoir
Ryesonggang No. 3	Tosan County	10.00	Reservoir
Ryesonggang No. 4	Kumchon Country	10.00	Reservoir
Ryesonggang No. 5	Kumchon Country	10.00	Reservoir
Kumya	Kumya County	8.00	Reservoir
Hoechang factory No. 1	Hoechang County	1.60	N/A
Hoechang factory No. 2	Hoechang County	1.60	N/A
Myongchon	Jangyon County	0.60	N/A
Hoechang factory No. 3	Hoechang County	0.20	N/A

Source: UNFCCC ,[33] UNDP DPRK[34]

The DPRK has an extensive history of SHP development. Before 1945, hydropower supplied 100 per cent of the electricity needs of the territory that became the DPRK. In the 1960s, the Government of the DPRK launched a programme of thermal power construction with the assistance of China and the Soviet Union to meet rising electricity demand and to address inefficiencies of aging hydropower plants. However, due to the multi-faceted economic crisis facing the country in the 1990s electricity production increasingly failed to meet demand and construction of SHP plants was promoted as a self-reliant solution. Nearly 7,000 SHP plants were constructed nationwide by 2005. The electricity supplied by these SHP plants did not meet expectations, and the programme was eventually discontinued.[31]

Apart from the announcements on the progress of the Tanchon power plant, information about hydropower projects in the DPRK is limited. In 2015, construction of new hydropower projects in Kangwon Province was announced for six different sites: Kosong, Hoeyang, Ichon, Phyonggang, Sepho and Anbyon. These projects are expected to be small-scale, but their exact capacity is unknown.[37] Furthermore, on the country's west coast many rivers, reservoirs, irrigation canal networks and tidal dykes are favourable for large-, medium- and small-sized hydropower development, indicating additional potential SHP capacity. These potential SHP sites vary in heads, with nearly 80 per cent of the sites having heads lower than 15 metres, of which 50 per cent have a head of 5 metres. Unfortunately, specific data on SHP potential capacity at these sites are not available.[24,38]

As part of the Sustainable Rural Energy Development Programme (SRED), micro-hydropower development has been encouraged for rural areas, however the programme was suspended in 2007 and was reformulated and approved by UNDP in 2010. In July 2013, as part of the SRED programme, the 600 kW Myongchon hydropower plant at Myongchon Co-operative Farm in Jangyon County was rehabilitated and the International Center on Small Hydro Power (ICSHP) provided technical support in its rehabillitation.[39] Another example of micro-hydropower is the 200 kW plant in Hoechang County, which is used to provide power to a food processing factory.[34]

RENEWABLE ENERGY POLICY

The national emblem of the DPRK includes the image of a hydropower dam, hence it is no surprise that the Government's energy policy is oriented towards non-fossil fuel options. These include formal policies for the development of decentralized small-scale power generation facilities and for the promotion of the development and use of renewable energy, namely the Law of Medium- and Small-Size Power Stations in the DPRK (2007) and the Law on Renewable Energy in the DPRK (2013). There are also policies targeting thermal power generation, which aim to solve the issue of ageing infrastructure and of the transmission and distribution network. Other approaches such as the expansion of the number of wind power plants are also being employed, which indicate the Government's efforts to reduce dependency on oil imports as it is unavailable domestically.[17] Furthermore, provinces, cities and counties are encouraged to develop medium- and small-scale power plants and ensure their steady operation.[24]

The DPRK is also a state party to several of the most important environmental conventions, such as the United Nations Framework Convention on Climate Change (UNFCCC). The country signed the Paris Agreement and prepared its own Intended Nationally Determined Contribution (INDC) in 2016 to reduce greenhouse gas emissions. In this document, the DPRK lists measures for the realization of greenhouse gas reduction targets, the construction and scaling-up of on-grid power plants as well as off-grid generating systems based on renewable energy resources. Mitigation measures prioritized for conditional contributions are also listed, such as the construction of a 2,000 MW nuclear power plant, 1,000 MW of grid-connected solar PV systems, a total of 500 MW of off-shore wind farms and another 500 MW of on-shore wind farms.[25] The Government aims to reach a total renewable energy capacity of 5,000 MW by 2044, with focus on wind power development.[11]

BARRIERS AND ENABLER FOR SMALL HYDROPOWER DEVELOPMENT

The main barriers to the development of SHP in the DPRK include:

- Lack of data and information on nearly every aspect of the national economy, as well as on the hydropower potential of rivers and specific sites;
- Lack of government funds and external financing due to sanctions and other factors;
- Extreme weather events causing damage to infrastructure;
- Inadequate technical capacities, particularly at provincial and local levels and inaccurate and untimely information and forecasts;
- Lack of domestic capacity to produce generation equipment including turbines, power systems and automation technologies.

Enablers for SHP development in the country include:

- Topography that suggests considerable remaining SHP potential in the form of small mountain rivers;
- Substantial potential for the rehabilitation of thousands of old SHP plants constructed in previous decades and likely being out of operation or operating far below nameplate capacity.

REFERENCES

1. World Bank Group (n.d). *World Development Indicators. Data Bank*. Available at http://databank.worldbank.org/data/reports.aspx?source=2&country=PRK (Accessed 6 June 2022).
2. Ministry of Land and Environment Protection of the Democratic People's Republic of Korea & the United Nations Environment Programme (UNEP) (2012). *Democratic People's Republic of Korea, Environment and Climate Change Outlook*. Available at https://wedocs.unep.org/handle/20.500.11822/9679 (Accessed 6 June 2022).
3. Korean Friendship Association (KFA) (n.d.). *Topography*. Available at https://korea-dpr.com/topography/ (Accessed 6 June 2022).
4. Savada, A. M., ed. (1993). *North Korea: A Country Study*. Washington: GPO for the Library of Congress.
5. European Space Agency (n.d.). *Earth from Space: Mount Paektu*. Available at https://www.esa.int/Applications/Observing_the_Earth/Mount_Paektu (Accessed 6 June 2022).
6. World Weather and Climate Information (2016). *Climate: Average Monthly Weather in Pyong Yang, North Korea*. Available at https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,Pyong-Yang,North-Korea (Accessed 6 June 2022).
7. Food and Agriculture Organization of the United Nations (FAO) (2011). *AQUASTAT Country Profile – Democratic People's Republic of Korea*. Available at https://www.fao.org/3/ca0392en/CA0392EN.pdf (Accessed 6 June 2022).
8. World Atlas (n.d.). *Major Rivers Of North Korea*. Available at https://www.worldatlas.com/articles/major-rivers-of-north-korea.html (Accessed 6 June 2022).
9. UNdata (n.d.). *Electricity, net installed capacity of electric power plants*. Available at https://data.un.org/Data.aspx?q=installed+capacity&d=EDATA&f=cmID%3aEC (Accessed 7 June 2022).
10. International Renewable Energy Agency (IRENA) (2021). *Energy Profile: Democratic People's Republic of Korea*. Available at https://www.irena.org/IRENADocuments/Statistical_Profiles/Asia/Democratic%20People%27s%20Republic%20of%20Korea_Asia_RE_SP.pdf (Accessed 7 June 2022).
11. Shin, H. (2019). *Cheap solar panels power consumer appliance boom in North Korea*. Reuters. Available at https://www.reuters.com/article/us-northkorea-solar-feature/cheap-solar-panels-power-consumer-appliance-boom-in-north-korea-idUSKCN1RT2P1 (Accessed 7 June 2022).
12. International Federation of Red Cross and Red Crescent Societies (2016). *Democratic People's Republic of Korea: Floods*. Available at https://reliefweb.int/sites/reliefweb.int/files/resources/IBDPRKfl030916.pdf (Accessed 7 June 2022).
13. UN Office for the Coordination of Humanitarian Affairs (2017). *Asia and the Pacific: Weekly Regional Humanitarian Snapshot (27 June - 3 July 2017)*. Reliefweb. Available at https://reliefweb.int/report/philippines/asia-and-pacific-weekly-regional-humanitarian-snapshot-27-june-3-july-2017 (Accessed 7 June 2022).
14. United Nations Development Programme Democratic People's Republic of Korea (UNDP DPRK) (2015). *Strengthening the Resilience of Communities through Community-Based Disaster Risk Management (CBDRM). Project Document.* Pyongyang: United Nations Development Programme, 08 October 2015.
15. Fifield, A. (2015). *North Korean drought is hobbling the power supply, and the economy with it*. Washington Post. Available at https://www.washingtonpost.com/world/asia_pacific/north-korean-drought-is-hobbling-the-power-supply-and-the-economy-with-it/2015/06/21/65e51c02-14ff-11e5-8457-4b431bf7ed4c_story.html?utm_term=.8b725cf3d6ba (Accessed 7 June 2022).
16. Frank, R. (2018). *Kim Jong un's 2018 New Year's Speech: Self-Confidence After a Tough Year.* 38 North. Available at http://www.38north.org/2018/01/rfrank010318/ (Accessed 7 June 2022).
17. Frank, R. (2018). *The North Korean Parliamentary Session and Budget Report for 2017.* 38 North. Available at http://www.38north.org/2017/04/rfrank042817/ (Accessed 7 June 2022).
18. U.S. Energy Information Administration (2018). *Korea, North, Analysis.* Available at https://www.eia.gov/beta/international/analysis.cfm?iso=PRK (Accessed 7 June 2022).
19. United Nations Development Programme Democratic People's Republic of Korea (UNDP DPRK) (2015). "Sustainable Energy Solutions for Rural Livelihoods in DPRK (SES)." *Democratic People's Republic of Korea (DPRK) Project Doucument.* Pyongyang: UN, 26 August 2015.
20. Jang, S. (2021). *North Korea's electricity situation worsens compared to last year*. Daily NK. Available at https://www.dailynk.com/english/north-koreas-electricity-situation-worsens-compared-to-last-year/# (Accessed 7 June 2022).

21. World Bank (n.d.). *Access to electricity (% of population) - Korea, Dem. People's Rep*. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=KP (Accessed 7 June 2022).
22. Fang, J. (2020). *United Nations Development Programme Terminal Evaluation of the "Sustainable Energy Solutions for Rural Livelihoods in DPRK" Project (SES Project).* United Nations Development Programme (UNDP). Available at https://erc.undp.org/evaluation/documents/download/15563 (Accessed 7 June 2022).
23. Global Environmental Facility (GEF) (2005). *Small Wind Energy Development and Promotion in Rural Areas (SWEDPRA)*. Available at https://www.thegef.org/projects-operations/projects/2397 (Accessed 7 June 2022).
24. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
25. United Nations Framework Convention on Climate Change (UNFCCC) (2016). *Intended Nationally Determeoined Contribution of Democratic People's Republic of Korea*. Pyongyang: UNFCCC, September 2016.
26. Macdonald, H. (2017). *North Korea begins work on major power station in Tanchon.* NK News. Available at https://www.nknews.org/2017/05/north-korea-begins-work-on-major-power-station-in-tanchon/ (Accessed 7 June 2022).
27. Makowsky, P. (2020). *The Tanchon Power Station Project: Progress Lagging*. 38 North. Available at https://www.38north.org/2020/11/tanchon201125/ (Accessed 7 June 2022).
28. Clean Development Mechanism (CDM) Executive Board (2006). *Project Design Document Form (CDM- SSC- PDD) Version 03.* UNFCCC, 22 December 2006.
29. Kim, J. (2017). *North Korea Installs Power Meters, Raises Rates in Pyongyang*. Radio Free Asia. Available at https://www.rfa.org/english/news/korea/power-meters-11072017112708.html (Accessed 21 June 2022).
30. Jang, S. (2020). *Pyongyang boosts state collection of electricity fees*. Daily NK. Available at https://www.dailynk.com/english/pyongyang-boosts-state-collection-electricity-fees/ (Accessed 21 June 2022).
31. Yoon, J.Y. (2011). *The DPRK Power Sector: Data and Interconnection Options*. NAPSNet Special Reports, 09 August 2011. Available at https://nautilus.org/napsnet/napsnet-special-reports/the-dprk-power-sector-data-and-interconnection-options/#ii-report-by-jae (Accessed 21 June 2022).
32. United Nations Country Team and DPRK Ministry of Foreign Affairs (2016). *The Strategic Framework for Cooperation between the United Nations and the Government of the Democratic People's Republic of Korea 2017-2021*. Pyongyang: United Nations, September 2016.
33. United Nations Framework Convention on Climate Change (UNFCCC) (2018). *Project Search: Database for PAs and PoAs.* Available at http://cdm.unfccc.int/Projects/projsearch.html (Accessed 7 June 2022).
34. United Nations Development Programme Democratic People's Republic of Korea (UNDP DPRK) (2013). *Pilot project to support socio-economic development of rural areas in DPRK (SED).* Project Document. Available at https://open.unido.org/api/documents/8687943/download/SED%20signed%20full.pdf (Accessed 21 June 2022).
35. UNIDO, ICSHP (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
36. UNIDO, ICSHP (2016). *World Small Hydropower Development Report 2016*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
37. Byrne, L. (2015). *North Korea announces more hydroelectric plants.* NK News. Available at https://www.nknews.org/2015/03/north-korea-announces-more-hydroelectric-plants/ (Accessed 7 June 2022).
38. Jin, R.Y., & Chol. R.S. (2010). *The Trend of Small Hydropower Research and Development in DPR of Korea.* Presentation at Hangzhou Regional Centre for Small Hydropower, Hangzhou.
39. Zhang, M., ed. (2013). UNDP-Aid Rehabilitation of 600kW Myongchon Hydropower Plant in DPRK Put-in Operation. *IN-SHP Newsletter* (International Center on Small Hydro Power), 2013: 1-2.

Japan

Tokihiko Fujimoto, Meiji University

KEY FACTS

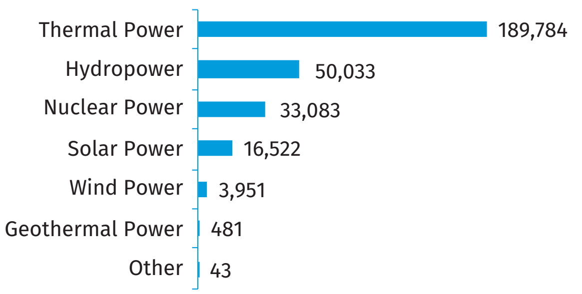
Population	12,5360,000 (2021)[1]
Area	377,962 km^2 [2]
Topography	The country consists of 6,852 islands lying in a volcanic zone. Sixty-seven per cent is of the country's land area is mountainous. The highest point is Mount Fuji, at 3,776 metres above sea level. The coastline is 29,751 kilometres long.[2]
Climate	The climate in Japan varies from south to north. While the south of the country lies in the tropical zone, the north has a subarctic climate. The average annual temperatures range from 23.8 °C in the southernmost city of Naha, Okinawa, to 10.0 °C in the northernmost city of Sapporo, Hokkaido. The capital city, Tokyo, had an average temperature of 16.5 °C in 2020.[3]
Climate Change	Over the period of 1896–2016, the mean annual temperature has been rising at a rate of 1.19 °C per 100 years, with springtime temperatures rising faster than other seasons, at a rate of 1.38 °C per 100 years.[4] In recent years, natural disasters linked to climate change have affected Japan on an annual basis, leading to human casualties. These have included the flooding caused by heavy rains in northern Kyushu (2017) and Kurashiki City in Okayama Prefecture (2018), the destructive typhoon flood on the Chikuma River in Nagano (2019) and the flooding of the Kuma River in Kumamoto Prefecture (2020).[5] Projections of future climate change in Japan predict a rise in temperatures of approximately 3 °C by 2076–2095, relative to the baseline period of 1980–1999, with temperatures in the northern and eastern parts of the country rising by as much as 3.5 °C.[6]
Rain Pattern	Japan experiences the East Asian monsoon. The average annual precipitation varies across the country, reaching 2,481 mm in Naha, 1,590 mm in Tokyo and 905 mm in Sapporo (2020).[3]
Hydrology	The rivers in Japan are short and fast-flowing, with steep gradients. Waterfalls are not uncommon in the mountainous landscape of the country. The longest rivers are the Shinano, Tone and Ishikhari Rivers.[7]

ELECTRICITY SECTOR OVERVIEW

The total installed capacity of Japan equalled 293,897 MW as of March 2020. This total included the installed capacity of thermal power plants at 189,784 MW (65 per cent); hydropower, including pumped storage, at 50,033 MW (17 per cent); nuclear power at 33,083 MW (11 per cent); solar power at 16,522 MW (6 per cent); wind power at 3,951 MW (1 per cent); geothermal energy at 481 MW (0.2 per cent); and other resources at 43 MW (less than 0.1 per cent) (Figure 1).[8]

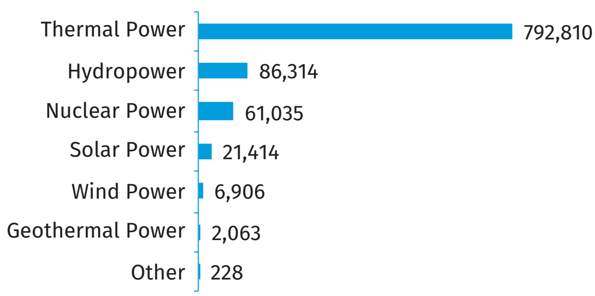
Annual electricity generation in Japan totalled 970,770 GWh between April 2019 and March 2020, with thermal power contributing 792,810 GWh (82 per cent) of the total, hydropower, including pumped storage, contributing 86,314 GWh (9 per cent), nuclear power contributing 61,035 GWh (6 per cent), solar power contributing 21,414 GWh (2 per cent), and wind power, geothermal energy and other resources contributing 6,906 GWh, 2,063 GWh, and 228 GWh, respectively (altogether less than 1 per cent) (Figure 2).

Figure 1. **Installed Electricity Capacity by source in Japan in 2020 (MW)**



Source: METI[8]

Figure 2. **Annual Electricity Generation by source in Japan in 2019–2020 (GWh)**



Source: METI[8]

Note: Data for the period between 1 April 2019 and 31 March 2020.

While the energy mix of Japan is dominated by thermal power, the focus on developing renewable energy resources including small hydropower (SHP), solar power, wind power and geothermal energy has progressively strengthened in recent years. Renewable energy sources including hydropower produced a total of 137,281 GWh between April 2019 and March 2020, accounting for approximately 14 per cent of total electricity generation. Furthermore, technological development and social testing of new energy technologies, such as hydrogen fuel cells, solar sharing with agriculture and smart grid systems, are underway.[8]

In 1995, the Government of Japan started the process of liberalizing the electricity sector, culminating in its full liberalization in April 2016. Following the liberalization, every consumer including households and retail dealers gained the ability to select electric utilities and power producers independently. Additionally, while only 10 power companies operated in the country prior to the liberalization, each serving a designated region, 749 new power producers were able to enter the market by March 2022 as a result of this process. The share of these new producers in the electricity market of Japan is approximately 16 per cent, based on the quantity of power sold.[9,10]

Although there are many newly established electric power companies, the Japanese electricity market is still dominated by 10 major regional power utilities, which form the Federation of Electric Power Companies (FEPC). They include Hokkaido Electric Power, Tohoku Electric Power, Tokyo Electric Power (TEPCO), Chubu Electric Power, Hokuriku Electric Power, Kansai Electric Power, Chugoku Electric power, Shikoku Electric Power, Kyushu Electric power and Okinawa Electric Power.

The institutions regulating the energy market in Japan include:

- Ministry of Economy, Trade and Industry (METI), which has the overall responsibility for energy policy in Japan;
- Agency for Natural Resources and Energy (ANRE) within METI, which is in charge of comprehensive energy policies to ensure strategic energy security, realize an efficient energy supply and promote environment-friendly energy policies;
- Ministry of the Environment, in charge of climate change and air pollution mitigation;
- Ministry of Land, Infrastructure, Transport and Tourism, in charge of energy efficiency and water resource management;
- Ministry of Education, Culture, Sports, Science and Technology, which is in charge of certain areas of energy research and development;
- Electricity and Gas Market Surveillance Commission (EGC), which monitors the electricity, gas and heat markets;
- Japan Fair Trade Commission (JFTC), responsible for monitoring competition in all sectors of the economy, including the electricity and natural gas industries;
- Nuclear Regulation Authority.[11]

Electricity tariffs in Japan are composed of a basic charge based on household size and priced per contract ampere, a usage charge based on used electric power and a surcharge for the promotion of renewable energy. The renewable energy surcharge is determined every year by the Government.

Table 1. **Basic Charges for Electricity per Contract Ampere**

Contract Ampere (A)		*10 A*	*15 A*	*20 A*	*30 A*	*40 A*	*50 A*	*60 A*
Basic charge (standard)	JPY	286	429	572	858	1,144	1,430	1,716
	USD	2.67	4.01	5.35	8.02	10.69	13.36	16.04
Basic charge (TEPCO Aqua Energy 100)	JPY	561	841	1,122	1,683	2,244	2,805	3,366
	USD	5.24	7.86	10.49	15.73	20.97	26.21	31.46

Source: TEPCO,[12] TEPCO[13]

Table 2. **Usage Charges for Electricity per kWh**

Standard (TEPCO)			*TEPCO Aqua Energy 100*		
	JPY/kWh	*USD/kWh*		*JPY/kWh*	*USD/kWh*
up to 120 kWh	19.88	0.19	up to 300 kWh	23.83	0.22
from 120 kWh to 300 kWh	26.48	0.25	above 300 kWh	30.57	0.29
above 300 kWh	30.57	0.29			

Source: TEPCO,[12] TEPCO[13]

Table 3. **Unit Price of the Renewable Electricity Surcharge in 2012–2022.**

Period	*Renewable energy surcharge*	
	JPY/kWh	*USD/kWh*
Aug. 2012 – Mar. 2013	0.22	0.0021
Apr. 2013 – Apr. 2014	0.35	0.0033
May 2014 – Apr. 2015	0.75	0.0070
May 2015 – Apr. 2016	1.58	0.0148
May 2016 – Apr. 2017	2.25	0.0210
May 2017 – Apr. 2018	2.64	0.0247
May 2018 – Apr. 2019	2.90	0.0271
May 2019 – Apr. 2020	2.95	0.0276
May 2020 – Apr. 2021	2.98	0.0279
May 2021 – Apr. 2022	3.36	0.0310

Source: Energy Information Center[14]

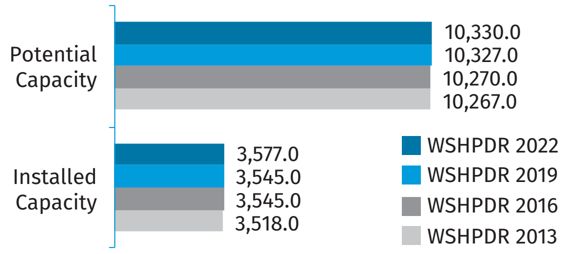
In recent years, a power sales package for renewable electricity has been available on the market. However, sales of this package have been low as all consumers already pay the surcharge for the promotion of renewable energy and the price of electricity is high. Tables 1 and 2 display the costs of regular electricity as well as, for the purposes of comparison, that of the "TEPCO Aqua Energy 100", a package plan aimed at reducing CO_2 emissions, which bundles electricity generated by TEPCO-operated hydropower plants. Table 3 displays the rates of the renewable energy surcharge between August 2012 and April 2022. As can be seen from the table, the surcharge has increased by a factor of 15 over the last decade.

SMALL HYDROPOWER SECTOR OVERVIEW

The definition of small hydropower (SHP) generally used in Japan is hydropower plants with an installed capacity of less than 10 MW. However, there is no clear definition and the classification changes depending on the policy and association.

The total installed capacity of SHP in Japan as of March 2019 was 3,577 MW. A further undeveloped potential of 6,753 MW was recognized, of which 62 MW were under construction.[15] Thus, approximately 35 per cent of the available SHP potential has been developed so far. As compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity of SHP in Japan has increased by 32 MW, while potential capacity increased by 3 MW (Figure 3).[16] The reasons for the increase in installed capacity include activities undertaken by electricity companies to harness superfluous water from constructed reservoirs and previously undeveloped river flow, local governmental policies promoting the construction of SHP and the activities of non-governmental organizations and agricultural cooperatives at the local level.[17,18]

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



Sources: METI,[15] *WSHPDR 2013*,[19] *WSHPDR 2016*,[20] *WSHPDR 2019*[16]

The development of hydropower has more than 130 years of history in Japan. In 1891, the Kyoto Keage plant became the first hydropower plant in commercial operation in the country. The plant provided power to general consumers and street trains. After several facility enhancements, the plant remains in operation today.[21] During the period of 1910–1925, nearly 100 hydropower plants were built annually. At the end of 1925, there were over 1,000 hydropower plants in Japan, with plants operating in every part of the country.[22,23]

Studies on national hydropower potential in Japan have been conducted five times: in 1910–1913, 1918–1922, 1937–1941, 1956–1959 and 1980–1985. All of these studies aimed to assess the theoretical, technical and economic potential and viability of hydropower development in the country, as well as installed capacities. In the fifth study, the overall assessment estimated the total national hydropower potential at 46,020 MW. The total installed capacity of existing hydropower plants over 10 MW (including those under construction, and excluding pumped storage plants) is approximately 19,000 MW, or about 41 per cent of the total potential. However, options for further development of large-scale hydropower are limited.[15,22]

A database of all hydropower plants in Japan in commercial use is maintained by the Japan Electric Power Civil Engineering Association (JEPOC). Meanwhile, a separate database maintained by J-watER lists SHP plants under 1 MW, including SHP plants for home use, micro- and pico-hydropower plants. Table 4 provides a list of some recently commissioned SHP plants in Japan, while Table 5 lists some planned and ongoing SHP projects.

Table 4. **List of Selected Operational Small Hydropower Plants in Japan**

Name	*Location*	*Capacity (kW)*	*Head (m)*	*Plant type*	*Operator*	*Launch year*
Matsuguma	Saga	30	20.4	Irrigation channel	Local Community	2020
Mitsuminekawa Honmonji 1	Shizuoka	120	11.2	Run-of-river	Private Company	2019
Mitsuminekawa Honmonji 2	Shizuoka	140	12.2	Run-of-river	Private Company	2019
Shinmiyakawa	Nagano	195	47.2	Run-of-river	Private Company	2019
Okawa Zyosuizyo	Shizuoka	186	85.5	Dam	Local Government	2018
Sakaguchi Zyosuizyo	Nagasaki	49	31.2	Dam	Local Government	2018
Gokayama Dam	Fukuoka	420	89.1	Dam	Prefectural Government	2018
Mitsuse	Saga	4	6.0	Run-of-river	Local Community	2018
Oitake	Kagoshima	30	67.0	Irrigation channel	Private Company	2018
Minakichikun	Kagoshima	45	8.7	Run-of-river	Private Company	2018
Shinmyo	Toyama	700	10.5	Irrigation channel	LID	2018

Name	*Location*	*Capacity (kW)*	*Head (m)*	*Plant type*	*Operator*	*Launch year*
Maebashi Akagiyama	Gunma	236	109.0	Irrigation channel	Local Government, LID	2018
Taguchi	Kagoshima	40	23.0	Irrigation channel	Private Company	2018
Shiraito Step 3	Fukuoka	15	25.2	Check dam	Cooperatives	2018
Taki (rehabilitation)	Iwate	450	25.8	Dam	Prefectural Government	1982/ 2018
Shiraito Step 2	Fukuoka	15	30.0	Run-of-river	Local Government	2017
Tateshina 4	Nagano	145	40.5	Irrigation channel	Private Company	2017
Tokunoshima Dam	Kagoshima	438	42.9	Dam	National Government Land Improvement District (LID)	2017
Kamuro	Yamagata	420	38.3	Dam	Prefectural Government	2017
Ohito	Miyazaki	50	85.0	Irrigation channel	Cooperatives	2017

Source: Watanabe et al.,[17] Alam et al.,[18] JEPOC,[24] J-watER,[25] NIW,[26] Takagi et al.[27]

Table 5. **List of Selected Planned Small Hydropower Projects in Japan**

Name	*Location*	*Capacity (kW)*	*Head (m)*	*Plant type*	*Developer*	*Planned launch year*	*Development stage*
Kuroki kawa	Fukuoka	12	7.0	Run off river type	Private Company	2021	Installation stage
Kawagoe	Kagoshima	15	18.1	Run off river type	Private Company	2021	Installation stage
Undecided	Kumamoto	50	32.5	Irrigation channel	Local Community	2021	Applied for grid connection certificate
Iki-Sagawa	Saga	200	67.0	Run off river type	Private Company	2022	Application preparation
Minami-dani	Shimane	50	71.2	N/A	Private Company	2022–2023	Planned
Aburai	Shimane	200	183.1	N/A	Private Company	2022–2023	Planned

Source: Fujimoto, T.[28]

The Ministry of the Environment of Japan developed an online system known as the Renewable Energy Potential System (REPOS), for the purpose of identifying and cataloguing potential renewable energy sites, including SHP. Listed potential SHP sites include existing irrigation channels and other water facilities.[29] Table 6 displays some examples of potential SHP sites available for development in the country.

Table 6. **List of Selected Small Hydropower Sites Available for Development**

Name	*Location*	*Capacity (kW)*	*Head (m)*	*Type of site*
Morotsuka Dam	Miyazaki	30.0	34.0	New
Taguchi B	Kagoshima	30.0	12.0	New
Taguchi C	Kagoshima	50.0	17.0	New
Iwayagawa	Saga	49.9	25.0	New
Yokotake Dam	Saga	49.9	23.4	New

Source: Fujimoto, T.[28]

According to the feed-in tariff (FIT) mechanism of Japan introduced in July 2012, the purchase price of hydropower varies depending on scale: less than 200 kW, from 200 kW to 1 MW and from 1 MW to 30 MW. Furthermore, in 2019 these categories were amended, with the 1 MW to 30 MW category being subdivided into categories from 1 MW to 5 MW and from 5 MW to 30 MW, with different purchase prices set for each category. Therefore, the price of medium and small-scale hydropower in the FIT system was divided into four levels. The tariffs for hydropower in April 2019–March 2020 were as follows:

- 5 MW to 30 MW: 20 JPY/kWh (0.19 USD/kWh);
- 1 MW to 5 MW: 27 JPY/kWh (0.25 USD/kWh);
- 200 kW to 1 MW: 29 JPY/kWh (0.27 USD/kWh);
- under 200 kW: 34 JPY/kWh (0.32 USD/kWh).[30]

The total capacity of medium and small-scale hydropower (less than 30 MW) certified under the FIT mechanism during the period of April 2019–March 2020 was 1,331 MW. The cumulative amount of purchased electricity under the system in the same period was 16,579 GWh and the total purchase price was JPY 4,390.8 billion (USD 41.6 billion).[31]

Since the publication of *WSHPDR 2019*, the number of SHP plants certified under the FIT mechanism has increased even though the actual installed capacities have barely changed. This is due to the fact that in many cases, FIT certification is approved for existing plants that have undergone renewal or rehabilitation. Local authorities often provide support for renewal and rehabilitation of deteriorated and discarded old SHP plants, as well as implementation of SHP on check dams and on dams and canals used for irrigation. As such, 'new' SHP potential can be often established using existing infrastructure.

RENEWABLE ENERGY POLICY

Since the 1970s and 1980s, the national energy and energy security policies of Japan have been aimed at reducing the dependency of Japan on petroleum, prompting the development of alternative energy sources and technologies. Alternative energy sources include new energy sources such as liquefied natural gas (LNG), nuclear power and improved coal technologies, as well as renewable energy sources.[22]

In 2008, the New Energy Law was put into effect in order to establish special measures for promoting the use of new energy. The concept of new energy was also redefined as including solar energy generation, wind power generation, biomass generation, biomass thermal generation, biomass fuel production, thermal energy conversion, geothermal power generation (binary system) and SHP (under 1MW).[22]

The Great East Japan Earthquake and the accident at the TEPCO Fukushima Daiichi Nuclear Power Plant became a major turning point in the energy policy of Japan. In order to facilitate the shift away from nuclear power as well as to reduce dependence on fossil fuels, the FIT framework was developed and introduced in July 2012. Tariffs are set for each renewable energy category (wind, solar, geothermal, hydropower, biomass) and are revised annually based on the degree of circulation and market conditions for each renewable energy source. The FIT requires electric utility companies to purchase electricity produced from renewable energy sources at a higher price than that from conventional fossil fuel-based energy. The purchase period set for tariffs is 20 years. FIT is designed so that authorities at all levels have a mandate to promote renewable energy.

The Fifth Energy Basic Plan, adopted in July 2018, again defined the rapid development of renewable energy to the status of the primary source of energy generation to be the key target.[32] To achieve this target, a part of the FIT framework will be modified as a feed-in premium (FIP), applied to large-scale and industrial solar power and wind power (excluding offshore wind power). Starting from April 2021, these two energy sources, go into the electric market independently with a competitive price based on the FIP.

SHP development in Japan has lagged behind solar and wind power and while the FIT covers plants of up to 30 MW, large-scale hydropower projects are no longer pursued in Japan. In recent years, small- and micro-scale hydropower (under 1 MW) is mainly being installed in stages by local communities as part of various community development schemes. Due to the gradual and community-driven nature of SHP development in Japan, innovations and cost reduction processes are still in progress.

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

The key law promoting SHP development in Japan is Law No. 358 from 29 December 1952, most recently amended by Law No. 37 from 2 May 2011, otherwise known as the “Act on the Promotion of Introducing Electricity into Farming and Fishing Villages”. The key aims of the law as originally conceived, outlined in Article 1, are the electrification of remote fishing and farming communities undersupplied by electricity, including those on remote islands, for the purpose of improving economic productivity as well as the general standard of living in these areas. The law outlines a crediting scheme for SHP projects by the Japan Finance Corporation and government subsidies and defines the operating entities taking advantage of this support as non-profit community organizations composed of individuals otherwise engaged in local industries such as fishing, farming and forestry.[33] The support schemes and regulations established by this law have ensured that historically, and until the present day, SHP development in Japan has been spearheaded by community efforts and will likely continue to be in the future.

The law and the history of SHP development in Japan flowing out of its implementation has important implications for future SHP initiatives. Firstly, it is important to note that SHP in Japan is mainly a community-based resource and communities must remain the primary controlling and operating actor. Consensus building and realignments of water rights with water users, circulation of expertise, as well as the development of rules in relation to water resource management based on public interest are vital.[34] Any development plans must consider not only the potential of the water resource in question, but also the natural and social environment and the history of past space use.[22,23] Finally, the issue of insufficient human resources for the coordination, planning, construction and maintenance must be taken into account, with focus on creating a framework for sustainable, stable communities.[35]

COST OF SMALL HYDROPOWER DEVELOPMENT

Table 7 shows the cost of the 30 kW Oitake SHP plant in Kagoshima, which was previously analyzed in a case study included in the *WSHDPR 2019*.[17] The total cost of the plant was JPY 74,076,000 (USD 692,299). Of this total, the cost of construction was approximately JPY 50,000,000 (USD 4,673) and therefore, the installation cost per kW, in this case, was approximately 1,666,667 JPY/kW (15,576 USD/kW).

Table 7. **Cost Breakdown of 30kW Oitake Small Hydropower Plant in Kagoshima**

Item name	*Unit cost (JPY (USD))*	*Number of units*	*Total price (JPY (USD))*
Construction costs			
Mechanical equipment cost		1	
Electrical equipment cost	34,000,000 (310,049)	1	34,000,000 (310,049)
Control panel cost		1	
IOT cost		1	
Civil engineering cost	12,000,000 (109,429)	1	12,000,000 (109,429)
PJ Management	2,000,000 (18,238)	1	2,000,000 (18,238)
Installation & commissioning	2,000,000 (18,238)	1	2,000,000 (18,238)
SUBTOTAL			**50,000,000 (455,955)**
Running costs			
Equipment replacement cost in 20 years	5,684,000 (51,833)	1	5,684,000 (51,833)
Inspection costs:			
Yearly inspection cost	258,000 (2,353)	16	4,128,000 (37,644)
Quinquennial inspection cost	466,000 (4,249)	4	1,864,000 (16,998)
Yearly personnel inspection cost	-	20	-
Water uses cost in 20 years	-	20	-
Land uses cost in 20 years	120,000 (1,094)	20	2,400,000 (21,886)
Miscellaneous costs: management cost by the owner, electrical security cost, etc.	500,000 (4,560)	20	10,000,000 (91,191)
SUBTOTAL			**24,076,000 (219,551)**
TOTAL			**74,076,000 (675,506)**

Source: NIW,[26] Fujimoto, T.[28]

EFFECT OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

In general, the strong commitment of Japan to renewable energy sources in the face of climate change is likely to benefit SHP. However, the sector is also likely to be affected by increased natural hazards over the coming decades, in particular, damage to SHP facilities by landslides and debris flows triggered by intense rainfall that are very common in Japan. According to climate predictions, the incidence of heavy rainfall is likely to increase by 10–25 per cent by the year 2100, relative to the end of the 20th century.[4] Additionally, the generation of suspended sediment in the rivers of Japan is expected to increase by anywhere from 8 per cent to 24 per cent by the 2090s relative to the 1990s.[36] This is likely to increase the operation and maintenance costs of SHP plants.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The SHP sector in Japan is complex, with a long history of development that, on the one hand, creates specific obstacles to the propagation of SHP, but, on the other hand, provides several advantages. Obstacles to SHP development in Japan can be summarized in the following points:

- SHP is primarily community-based and extensive engagement and consultation with the local community, as well as the direct involvement of community-based organizations, is necessary in the case of most projects;
- Small communities in Japan often have insufficient human resources for implementing SHP projects, therefore, the long-term viability of any SHP project ultimately depends on the sustainability of the host community;
- Difficulties with building a wholesale electricity market and implementing a power system reform;
- Difficulties with researching and developing independent community grid systems;
- Lack of clarity on the details of electricity market liberalization, including who will bear the costs of system connection and wide-area maintenance and how to formulate disclosure rules for related information;
- Recent policy focus on the development of wind and solar power.
- On the other hand, several enabling factors for SHP development exist. These include:
- Abundant remaining hydropower potential that has been well-mapped but is generally not suited for large-scale hydropower;
- A long history of SHP development and a well-established framework for community engagement and operation of SHP projects;
- Established financial support schemes in the form of loans, subsidies and FITs.

REFERENCES

1. Statistics Bureau, Ministry of Internal Affairs and Communication (2021). *Statistics.* Available at http://www.stat.go.jp/data/jinsui/new.htm [in Japanese] (Accessed 11 June 2021).
2. Japan Institute of Country-ology and Engineering (JICE) (n.d.). *Statistics.* Available at http://www.jice.or.jp/knowledge/japan [in Japanese] (Accessed 11 June 2021).
3. Japan Meteorological Agency (JMA) (n.d.). *Statistics.* Available at http://www.data.jma.go.jp/obd/stats/etrn/index.

php (Accessed 11 June 2021).

4. The Government of Japan (2017). *Japan's Seventh National Communication under the United Nations Framework Convention on Climate Change (NC 7).* Available at https://unfccc.int/sites/default/files/resource/4092715_Japan-NC7-2-NC7-JPN-E.pdf (Accessed 11 June 2021).
5. Ministry of the Environment (2020). *White Paper on Environment/ Sustainable Society/ Biodiversity* [in Japanese].
6. Japan Meteorological Agency (JMA) (2013). *Global Warming Project Vol. 8 (GWPV8). Summary of future projections.* Available at http://ds.data.jma.go.jp/tcc/tcc/products/gwp/gwp8/html/section2.html (Accessed 11 June 2021).
7. Ministry of Land, Infrastructure, Transport and Tourism (2017). *The Data Book of Rivers in Japan*. Available at http://www.mlit.go.jp/river/toukei_chousa/kasen_DB_2017.pdf [in Japanese] (Accessed 11 June 2021).
8. Ministry of Economy, Trade and Industry (METI), Agency for Natural Resources and Energy (n.d.). *Statistics.* Available at http://www.enecho.meti.go.jp/statistics/electric_power/ep002/results_archive.html (Accessed 11 June 2021).
9. Ministry of Economy, Trade and Industry, Agency for Natural Resources and Energy (2020). *Energy White Paper 2020* [in Japanese].
10. Ministry of Economy, Trade and Industry, Agency for Natural Resources and Energy (n.d.). *List of Registered Retail Electricity Providers.* Available at / [in Japanese] (Accessed 15 March 2022).
11. International Energy Agency (IEA) (2016). *Energy Policies of IEA Countries: Japan*. Available at https://iea.blob.core.windows.net/assets/0544f290-7b29-4733-a6c4-fb18d33b0ac4/EnergyPoliciesofIEACountriesJapan2016.pdf (Accessed 12 June 2021).
12. Tokyo Electric Power Company (TEPCO) (n.d.). *Contract for home lighting and outlets. Recommended private charge plan for a wide range of households.* Available at https://www.tepco.co.jp/ep/private/plan/old01.html [in Japanese] (Accessed 12 June 2021).
13. Tokyo Electric Power Company (TEPCO) (n.d.). *Household plan. Aqua Energy 100*. Available at https://www.tepco.co.jp/ep/eco/plan/private/detail.html [in Japanese] (Accessed 12 June 2021).
14. Energy Information Center (n.d.). *About the renewable energy power promotion surcharge*. Available at https://pps-net.org/statistics/renewable [in Japanese] (Accessed 12 June 2021).
15. Ministry of Economy, Trade and Industry (METI), Agency for Natural Resources and Energy (2020). *Hydropower by output capacity*. Available at https://www.enecho.meti.go.jp/category/electricity_and_gas/electric/hydroelectric/database/energy_japan006/ [in Japanese] (Accessed 12 June 2021).
16. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
17. Watanabe, Y., Alam, Z.M., Rusmiputro, R.R., Okajima, K., Yamamoto. S., Rahadian, F., Kumar, A., & Fujimoto, T. (2020). 30 kW Oitake Small Hydropower Plant in Kagoshima Prefecture, Japan. in LIU, D., LIU H., WANG, X., and Kremere, E., eds. (2019). *World Small Hydropower Development Report 2019 Case Studies, pp.37-40.* United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
18. Alam, Z.M., Watanabe, Y., Rusmiputro, R.R., Okajima, K., Yamamoto, S., Sato, T., Rahadian, F., Kumar, A., & Fujimoto, T. (2022). A case report on socio-economic development in remote mountainous community by establishing the community – renewable energy enterprise through installing SHP: 30kW Matsuguma Village's SHP in Yoshinogari town, Saga prefecture, Japan. in LIU, H., ed. (2022) *World Small Hydropower Development Report 2022 Case Studies*. United Nations Industrial Development Organization; International Centre on Small Hydropower, (scheduled).
19. UNIDO, ICSHP (2013). *World Small Hydropower Development Report 2013.* United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
20. UNIDO, ICSHP (2016). *World Small Hydropower Development Report 2016.* United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
21. Kansai Electric Power Company (KEPCO) (2020). *History of the Keage power plant.* Available at https://www.kepco.co.jp/energy_supply/energy/newenergy/water/plant/tour_keage/pdf/keage_ayumi.pdf [in Japanese] (Accessed 12 June 2021).
22. Murota T., Kurasaka H., Kobayashi H., Shimatani Y., Yamashita T., Fujimoto T., Miura S. & Morotomi T. (2013) *Community Energy.* Nobunkyo, Tokyo, Japan. [in Japanese]
23. Fujimoto, T. (2022). *River Administration and Water Resource Management in Modern Japan: Based on the Research of River Engineer and Technical Bureaucrats* in Yamamoto, S., Sugawara, D. & Yamada, K. (eds.). *Island Civilizations: Implications for the Future of the Earth. Springer Earth System Sciences, Springer Nature Singapore* (Chapter 16).
24. Japan Electric Power Civil Engineering Association (JEPOC) (n.d.). *Hydropower plant database*. Available at http://www.jepoc.or.jp/hydro/ [in Japanese] (Accessed 12 June 2021).
25. J-watER (n.d.). *Small hydropower database.* Available at http://j-water.org/db_form/ [in Japanese] (Accessed 12 June 2021).
26. Nakayama Iron Works (NIW) (n.d.). *Effective micro hydro system.* Available at https://www.ncjpn.com/en/products/effective-micro-hydro-system/ (Accessed 12 June 2021).
27. Takagi, M., Watanabe, W., Ikematsu, S., Hayashi, T., Fujimoto, T. & Shimatani, Y. (2014). 3D-printed Pelton turbine: How to produce effective technology linked with global knowledge. *Energy Procedia, 61*, 1593-1596, presented at International Conference on Applied Energy 2014. Available at https://www.sciencedirect.com/science/article/pii/S1876610214032081?via%3Dihub (Accessed 12 June 2021).
28. Fujimoto, T. (2021). Unpublished research and personal communication with stakeholders.

29. Ministry of the Environment (n.d.). *Renewable Energy Potential System (REPOS), Homepage*. Available at http://www.renewable-energy-potential.env.go.jp/RenewableEnergy/gis.html?energy=water [in Japanese] (Accessed 12 June 2021).
30. Ministry of Economy, Trade and Industry (METI), Agency for Natural Resources and Energy (2021). *Price list for FY2021 and beyond*. Available at https://www.enecho.meti.go.jp/category/saving_and_new/saiene/kaitori/fit_kakaku.html [in Japanese] (Accessed 15 March 2022).
31. Agency for Natural Resources and Energy (2021). *Fixed price purchase system information publication website*. Available at https://www.fit-portal.go.jp/PublicInfoSummary [in Japanese] (Accessed 12 June 2021).
32. Ministry of Economy, Trade and Industry, Agency for Natural Resources and Energy (2018). *Fifth Energy Basic Plan*. Available at https://www.enecho.meti.go.jp/category/others/basic_plan/ [in Japanese] (Accessed 12 June 2021).
33. Government of Japan (1952). *Act on the Promotion of Introducing Electricity into Farming and Fishing Villages*. Available at https://elaws.e-gov.go.jp/document?lawid=327AC1000000358 [in Japanese] (Accessed 12 June 2021).
34. Fujimoto, T. & Kagohashi, K. (2019). Community-Led Micro-Hydropower Development and Landcare: A Case Study of Networking Activities of Local Residents and Farmers in the Gokase Township (Japan). *Energies, 12*(6), 1033, 1-9. Available https://www.mdpi.com/1996-1073/12/6/1033/pdf (Accessed 12 June 2021).
35. Alam, Z.M., Rusmiputro, R., Watanabe, Y., Sato, T. & Fujimoto, T. (2022). *Small Hydropower Development to Civilized Rural Communities in Japan: Integrated and Combined Approach for Cultivating Water Resources, Developing Appropriate Technology and Starting Local Busines*ses in Sugawara, D. & Yamada, K. (eds.), *Island Civilizations: Implications for the Future of the Earth. Springer Earth System Sciences, Springer Nature Singapore* (Chapter 17).
36. Mouri, G., Golosov, V., Chalov, S., Takizawa, S., Oguma, K., Yoshimura, K., Shiiba, M., Hori, T. & Oki, T. (2013). Assessment of potential suspended sediment yield in Japan in the 21st century with reference to the general circulation model climate change scenarios. *Global and Planetary Change, 102,* 1-9.

Mongolia

Ayurzana Badarch, Mongolian University of Science and Technology; and Gendensuren Yondongombo, Monnationenergy NGO

KEY FACTS

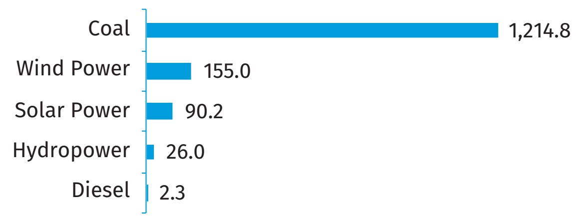
Population	3,296,866 (2019)[1]
Area	1,564,120 km[2]
Topography	Mongolia is a landlocked country located on a vast plateau with an average elevation of 914–1,524 metres above sea level. The southern, northern and western regions are mountainous with an average elevation of 1,580 metres. The plateau consists of arid and semi-arid pasture lands and the Gobi Desert, while the northern mountain ranges form the southern front of Siberia. The eastern side of the Altai Mountains dominates in the west of the country. There also lies the highest peak in Mongolia, Huyten Orgil, at 4,374 metres above sea level.[2]
Climate	Due to being located far from the sea, Mongolia has a sharply continental climate. The temperature varies not only across seasons, but also during the day.[3] The climate in the northern and western parts of the country is very cold, while in the eastern and southern parts it is cold only in winter. The average annual temperature is approximately 0.2 °C.[4] The ground freezes down to 3 metres in winter and the total number of cold days is 160–220 a year.[5]
Climate Change	The average annual temperature increased by 2.14 °C over the last 70 years due to climate change.[5] Although the average annual precipitation rate has not significantly changed, local and temporal changes in the rain pattern have been observed, including sudden heavy rains and prolonged periods of drought.[4,6]
Rain Pattern	Precipitation in the country is defined by the geographical and topographical conditions, such as lakes and mountains. In the north, annual precipitation averages 250–390 mm, while it is only approximately 70–150 mm in the south. Most precipitation falls in the form of rain in the warm months and less in the form of snow in winter.[6]
Hydrology	Mongolia is situated on three international river basins: the Arctic Ocean basin (AOB), the Pacific Ocean basin (POB) and the Central Asian internal drainage basin (CAIDB). The headwaters of rivers in these three basins arise in the three main mountainous regions: Altai, Khangai and Khentey. The rivers starting from the Khangai Mountains in the AOB and from the Khentey Mountains in the POB flow northwards and eastwards, respectively. Major rivers in the CAIDB end as lakes or become dry channels. All rivers in Mongolia are covered with 1–2 metres of ice in winter. The rivers are fed by permafrost, glaciers, snow and springs fed by precipitation. Based on historical data, annual water runoff of all rivers in Mongolia is estimated at 34.6 km^3.[7]

ELECTRICITY SECTOR OVERVIEW

The electricity sector of Mongolia consists of five independent electric systems: the Central Regional Integrated Power Grid (CRIPG), which has most sources and consumers; Western Regional Integrated Power Grid (WRIPG); Eastern Regional Integrated Power Grid (ERIPG); Altai-Uliastai Integrated Power Grid (AUIPG) and Southern Energy System (SES). Mongolia consumes approximately 8.5 TWh of electricity annually, with roughly 80 per cent of consumption coming from local sources and 20 per cent being imported from Russia and China. Most of the imported electricity comes from China to the Oyu Tolgoi mine. The central and western regions import approximately 300 GWh of electricity annually from Russia.[8]

As of 2019, the total installed capacity of Mongolia stood at 1,309.5 MW, with renewable sources accounting for 18 per cent of the total.[8] In 2020, the country's installed capacity reached 1,488.3 MW (Figure 1).[9]

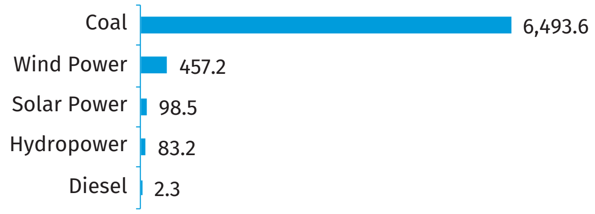
Figure 1. **Installed Electricity Capacity by Source in Mongolia in 2020 (MW)**



Source: MOE[9]

In 2020, a total of 7,134.9 GWh of electricity was generated in the country.[9] Ninety-one per cent of electricity production came from coal-fired combined heat and power (CHP) plants, almost 9 per cent was produced by renewable energy sources and the remaining 0.03 per cent came from local diesel generators (Figure 2).

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



Source: MOE[9]

According to the National Statistics Office, the number of households supplied with electricity in the country increased from 548,517 in 2010 to 732,494 in 2020. At the same time, the number of households without electricity decreased from 23,610 in 2010 to 4,817 in 2020.[10]

The energy and electricity sector of Mongolia is governed by the Ministry of Energy (MOE) and regulated by the Law on Energy, Law on Energy Conservation, Law on Renewable Energy and other related regulations and bylaws. The role of MOE is to provide accurate, timely and prompt consultation as well as an all-round support for the implementation of the Government's plans to improve the energy sector. According to the Energy Law, the Energy Regulatory Commission (ERC) is responsible for regulating energy production, transmission, distribution, dispatching and supply.[11] The objectives of ERC include ensuring conditions for fair competition among sector licensees and protecting the rights of both consumers and licensees. Another important agency is the National Renewable Energy Centre, which is responsible for promoting renewable energy technologies and for supporting renewable energy research projects nationwide.

The Government of Mongolia has singled out nine priority areas for action in the energy sector from 2020 to 2024. The most important targets are security of the energy system, support for new sources and renewable energy production.[12]

Electricity tariffs in Mongolia are not uniform and vary depending on the grid, consumer type and type of the electricity metre installed. Electricity tariffs are set by ERC (Table 1).[11] In September 2002, ERC introduced the Single Buyer Model for the CRIPG. The single buyer is the state-owned Central Regional Electricity Transmission Network (CRETN), which purchases electricity from power sources, including additional imports, and sells it to 11 electricity distribution companies. Following a successful spot market trial in 2005, in 2006 the National Dispatching Centre was selected to act as the spot market operator. The spot market includes five co-generators and is operated based on real-time consumption and scheduled electricity rate difference. In 2007, ERC also started an auction market, where the incremental electricity demand is auctioned off among generation licensees for the best reduced tariff percentage. The auction market is also operated by the National Dispatching Centre.

Table 1. **Average Electricity Tariffs for Residential and Commercial Consumers in Mongolia in 2021**

Electric grid	*Tariff in MNT/kWh (USD/kWh)*
CRIPG	168.8 (0.059)
AUIPG	151.6 (0.053)
WRIPG	173.1 (0.061)

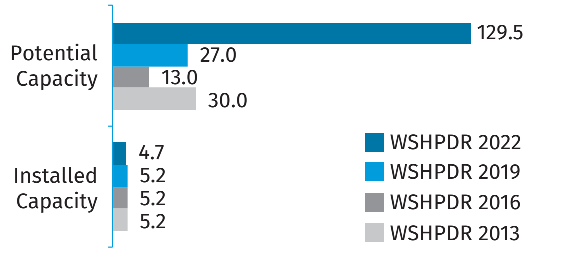
Source: ERC[13]

SMALL HYDROPOWER SECTOR OVERVIEW

Mongolia has no official definition of small hydropower (SHP). However, the international definition of up to 10 MW has been in use.

As of 2021, there were 10 SHP plants with a total installed capacity of 4.7 MW (Table 2).[14] The total SHP potential of Mongolia remains unknown, however, based on data on planned projects and data reported in literature, it is possible to conclude that there is at least 129.5 MW of potential capacity available.[15,16,17,18] This total includes a number of sites with a combined potential of 74.4 MW that were identified in investigations carried out by former Soviet and Mongolian institutes.[17] Furthermore, in 2008, based on a field survey and existing hydrological data, the National Renewable Energy Centre of Mongolia identified an additional potential of 20 MW from another 17 sites that had not been reported elsewhere before.[18] Finally, the potential estimate total also includes a number of planned SHP projects, which do not coincide with the mentioned studies (Table 3). Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed SHP capacity of Mongolia has slightly decreased (from 5.2 MW reported in the previous edition) due to the exclusion from the total of the destroyed 530 kW Kharkhorin plant. On the contrary, the potential capacity estimate increased due to access to more accurate data (Figure 3).

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



Source: CIF,[14] ХИ & УББСХТ,[15] Badarch & Yondongombo,[16] Hydroplan Group,[17] Boldbaatar,[18] *WSHPDR 2013*,[19] *WSHPDR 2016*,[20] *WSHPDR 2019*[21]

Five of the existing SHP plants — Galuutain, Hunguin, Tosontsengel, Bogd and Guulin — operate only in the summer time. The other five have been abandoned or stopped operating since the supplier has been connected to the grid. The total annual production of SHP plants in Mongolia is approximately 5.4 GWh per year, of which 4.9 GWh is generated annually by the SHP plants in active operation.[22] The Erdenebulgan, Uyench, Munkh-khairkhan, Mankhan and Undurkhangai SHP plants would be able to operate only after a major restoration.

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

Plant	*Location*	*Capacity (MW)*	*Head (m)*	*Plant type*	*Operator*	*Launch year*
Galuutain	Galuutain River, Zawkhan	0.11	1.2	Run-of-river	AUIPG	2008
Hunguin	Hungui River, Zawkhan	0.15	7.0	Run-of-river	AUIPG	2008
Tosontsengel	Ider River, Zawkhan	0.38	3.3	Run-of-river	AUIPG	2006
Erdenebulgan	Egiin River, Khuwsgul	0.20	–	Diversion	CRIPG	2006
Bogd	Uliastai River, Zawkhan	2.00	35.0	Diversion	AUIPG	2005
Uyench	Uyench River, Khovd	0.96	14.0	Diversion	WRIPG	2005
Munkh-khairkhan	Tsenkher River, Khovd	0.15	7.5	Diversion	WRIPG	2003
Guulin	Zawkhan River, Govi-Altai	0.40	40.0	Diversion	AUIPG	1998
Mankhan	Tugrug River, Khovd	0.15	13.8	Diversion	WRIPG	1998
Undurkhangai	Chigj River, Uvs	0.20	1.9	Diversion	WRIPG	1989
Total		**4.67**				

Source: CIF,[14] Badarch & Yondongombo[16]

The theoretical and technical hydropower potential of the Mongolian rivers was first determined in 1976 as part of a scheme on integrated use and protection of water resources. The total theoretical hydropower potential is estimated at 50,513 GWh, of which 15,200 GWh is the technical potential. In 1994, the Ministry of Nature updated the theoretical hydropower potential to 56,200 GWh, with 36,700 GWh of potential identified in POB, 4,907 GWh in AOB and 14,592 GWh in CAIDB.[7] The theoretical and technical hydropower potential estimates need to be updated clearly defining the exploitable small, medium and large hydropower potentials. As of 2021, there was no ongoing SHP construction work in Mongolia.

A number of hydropower projects of various capacities, located on all big rivers across Mongolia have been proposed by both private and governmental entities. The projects considered feasible are mainly located in western Mongolia, where the high head can be utilized instead of the discharge. The Ministry of Nature, Environment and Tourism of Mongolia has selected 33 potential hydropower projects, including small- and large-scale ones, to be implemented until 2040 with the help of local engineering firms under the project called Blue Horse.[15] Some of the SHP sites indicated in the Blue Horse project as well as previous potential proposals are listed in Table 3.

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

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Plant type*	*Developer*	*Planned launch year*	*Development stage*
Bulagt Uul	Ongi River, Uvurkhangai	4.0	16	Reservoir	GHP LTD	2021–2025	Feasibility study
Baidrag	Baidrag River	8.0	54	Reservoir	Monhydro construction LTD	2026–2030	Feasibility study
Eg-Khengertei	Egiin River	6.0	30	Diversion	Hydro Engineerging LTD	2035–2040	Pre-feasibility study
Teeliin	Teel River	2.2	10	Reservoir	Hydro Engineerging LTD	2035–2040	Pre-feasibility study
Ulgii	Khovd River	9.7	20	Reservoir	Usny Erchim LTD	Undefined	Feasibility study

Source: ХИ & УББСХТ,[15] Badarch & Yondongomb[16]

SHP in Mongolia is generally understood as a seasonal source of electricity, since the existing SHP plants cannot operate during the cold winters, when electricity demand is the highest. Instead, SHP is regarded as a suitable source of electricity for agricultural and industrial purposes in the summer time.

SMALL HYDROPOWER PROJECTS AVAILABLE FOR INVESTMENT

Two SHP projects available for investment are the Baidrag and Bulagt-Uul sites (Table 3). Both projects are developed by private companies and are open for investment. The Baidag site was first identified in 1981 for the development of a large-scale irrigation system in the Bayankhongor Province. In 1985, the feasibility study and technical drawings for the Baidrag SHP project were prepared. Due to political changes in 1990, the project was no longer supported by the Government. In 2010, the national consulting firm named Monhydro construction LTD updated the feasibility study through a detailed investigation of the site and hydrology.

RENEWABLE ENERGY POLICY

Within the framework of national laws related to water and energy, a number of national programmes have been implemented. For example, the national renewable energy programme started in 2005 was completed in 2020 with adequate outcomes achieved for all types of renewable energy sources. The Galuutain, Hunguin, Tosontsengel and Erdenebulgan SHP plants were developed as part of this programme. The national water programme addressing hydropower development in terms of water resources development also expired in 2020. It, however, demonstrated poor accomplishment in respect to SHP development due to a number of reasons, including the poor institutional structure for programme implementation, lack of follow-up regulations and investment and unclear action strategy for SHP development.

In 2015, the parliament of Mongolia, the State Great Khural, approved the energy policy until 2030 with two stages of implementation.[23] Under this policy, the share of hydropower, including SHP, could reach 10 per cent of the country's total installed capacity in the first stage by 2030.[24] The follow-up government resolution from 2018 on a six-year programme readdressed some goals, including hydropower development not realized in the past.[25] The resolution promoted the development of SPH that can operate continuously throughout the year. However, the policy does not address climate change adaptation and CO_2 emission reduction. In the same year, the Government of Mongolia put forward another energy programme focusing on energy conservation, which aims to cut 620 ktCO_2 emissions by curbing wasteful consumption of electricity, implementing new technology and improving the legal environment.[26]

As of 2021, hydropower development, including SHP plans, which are not defined separately, has been identified in the country's sustainable development goals and long-term national development plans.[27] The Blue Horse project is included in the Vision 2050 development policy.

The Law on Renewable Energy was first introduced in 2007 and successively amended in 2015 and 2019. The revised law redefines the tariffs for solar and wind power connected to the grid as well as regulates technical issues and price competitiveness or tendering for the implementation of renewable energy projects. It also stipulates that the responsible company must be financially viable to ensure a successful implementation of the project. In addition, a system of prices, tariffs and incentives was established in response to the increasing use of low-capacity renewable energy sources from households to the industrial level in recent years.[28] The Government expects that the revised law will help increase the share of renewable energy sources in the country's energy mix to 30 per cent, including 10 per cent for hydropower. Under this law, as of 2019, ERC had issued licenses for a total of 35 legal entities to construct renewable energy projects with a combined capacity of 1,379.8 MW, including 3 legal entities with 217.4 MW of hydropower capacity.[8]

Another goal of the Renewable Energy Law is to reduce costs and create a real market price for the technologies, with the changes in solar and wind power prices and tariffs making it possible not to increase the renewable energy support tariffs. According to the law, the tariff range given in Table 4 should be used as a reference for ERC to define the tariffs for the commissioned projects.[28]

Table 4. **Feed-in Tariffs for Renewable Energy Sources in Mongolia**

Electricity source	*Hydropower up to 5 MW*	*Hydropower above 5 MW*	*Wind power*	*Solar power*
Tariff range (USD/kWh)	0.045–0.060	to be defined by ERC based on feasibility study	up to 0.085	up to 0.120

Source: State Great Khural[28]

Comparing the electricity tariffs in Table 1 and the feed-in tariffs (FITs) in Table 4, it can be seen that wind and solar power generators sell electricity to the grid at a high price. The compensating mechanism for the difference between the FITs and the electricity tariffs is defined in the Law on Renewable Energy.

Consulting engineers and practitioners in the hydropower sector criticize the uneven tariff range depending on the energy source as defined in the Law on Renewable Energy. It is suggested that foreign investors into SHP projects will not be interested because of this tariff range. The relatively high FITs for wind and solar power create a favourable environment for these sources and shorten the payback period for such projects in comparison to SHP.

There are no specific SHP legislation or regulations in Mongolia.

COST OF SMALL HYDROPOWER DEVELOPMENT

According to one economic assessment, hydropower projects in Mongolia with an investment of up to 5,000 USD/kW can be considered profitable.[29] In line with this, the majority of previously commissioned projects can be evaluated as profitable, while the planned SHP projects listed in Table 3 can be considered low-profit.[15] The exact cost breakdown of these projects has not been made accessible to the public.

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER DEVELOPMENT

According to the Law on Renewable Energy and the resolution of the State Commission for the State Great Khural, every electricity consumer is required to pay the so-called renewable energy support tariff to compensate for the tariff difference between the conventional CHP generation and renewable energy generation (specifically, solar and wind power). This renewable energy support tariff is one of the financial mechanisms available for SHP projects in Mongolia.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

It has been repeatedly noted that climate change has negatively impacted the water resources in Mongolia.[30] The rivers in the country are sensitive to small changes in temperature, precipitation and land use. In this regard, the diversion type of SHP can be affected by the climate crisis more than conventional types of SHP plants. As an example, the Uvurkhangai SHP plant on the Chigj River was abandoned because of a decline in the river flow, leading to an insufficient water level for running the turbine.[7] No measures have been taken to adapt to the changed conditions after the plant was connected to the electric grid and the technical worker left for a full-time job.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

There is a need for SHP development all over Mongolia, especially in rural areas. However, a number of barriers pertain and hinder development, including the following:

- The low FITs for hydropower remain the biggest barrier for investment in SHP projects in Mongolia. The demands to increase or equalize the tariffs submitted by relevant parties during the process of law amendment were not supported.
- The lack of specific regulations, legislation and policy on SHP creates ambiguities for SHP projects in all stages of approval.
- In winter, small- to medium-sized rivers freeze over, which creates seasonal difficulties for SHP operation (ice, declined discharge in winter and geomorphological changes in river channels) and makes projects less profitable both in the development stage and during operation. The technical possibility of operating SHP continuously during the whole year should be studied in the planning phase. The lessons learned from diversion type SHP projects in the country, such as the Uwurkhangai and Munkhhairkhan plants, show that the plants located on rivers vulnerable to the climate crisis must have a reservoir to ensure enough water resources when the river discharge is declined.
- Political and social responses to the environmental impact of hydropower is strong in Mongolia. It is important to improve public awareness about SHP and ensure that projects are judged based on the environmental impact assessment and mitigation measures.
- The lack of human resources in the development and operation of SHP projects is crucial as the abandonment of plants happens mainly because of the lack of proper maintenance and skilled employees. For SHP plants with seasonal operation, the unemployment period for the employees must also be regulated.

In spite of the above barriers, there are also a number of enabling factors for SHP development in the country, particularly the existing institutional structure:

- The State Great Khural is responsible for amending or enacting a law to create favourable legislation for SHP development, including setting reasonable FITs for hydropower development, especially SHP, and, thus, incentivizing investment.
- Government agencies, such as the Renewable Energy Centre and the Water Agency, are responsible for initiating supportive regulations and policy for SHP. They resolve issues related to investment and development as well as incorporate private enterprises for the approval of the Government and the State Great Khural.

It is suggested that in order to facilitate SHP development in the country, the FITs for hydropower should be increased. Furthermore, the abandoned SHP plants could be restored and the share of electricity production should be regulated to utilize SHP in summer. In this regard, management of human resources should be addressed. Finally, research institutions with government support should carry out research on the SHP potential and operation challenges, including capacity building.

REFERENCES

- Mongolian Statistical Information Service (2020). *Population in Mongolia*. Available at https://www.1212.mn/stat.aspx?LIST_ID=976_L03 (Accessed 28 May 2021).
- Mongolia Travel Advice (n.d.). *Mongolia Topography: An overview*. Available at http://www.mongolia-travel-advice.com/mongolia-topography.html (Accessed 28 May 2021).
- Food and Agriculture Organization of the United Nations (FAO) (1998). *Asia-Pacific Forestry Sector Outlook Study: Country report - Forestry of Mongolia*. Available at http://www.fao.org/3/w8302e/w8302e00.htm#Contents (Accessed 28 May 2021).
- National Agency of Metereology and Environmental Monitoring (2017). *Climate of Mongolia*. Available at http://tsag-agaar.gov.mn/atmosphere (Accessed 28 May 2021).
- Гомболуудэв, П. (2019). *Монгол орны байгаль орчны сүүлийн 30 жилийн динамик Боть 1: Монгол орны уур амьсгалын өөрчлөлт, цөлжилт*. Улаанбаатар: Байгаль орчин ногоон хөгжлийн яам [In Mongolian].
- Batima, P., Natsagdorj L., Gombluudev P. & Erdenetsetseg B. (2005). *Observed climate change in Mongolia*. Assessments of Impacts and Adaptations of Climate Change Working Paper No.12. Available at http://www.start.org/Projects/AIACC_Project/working_papers/Working%20Papers/AIACC_WP_No013.pdf (Accessed 28 May 2021).

- Балдандорж, Ц. (2017). *“БАЙГАЛЬ ОРЧНЫ ТӨЛӨВ БАЙДЛЫН СУУЛИЙН 30 ЖИЛИЙН ХУВЬСАЛ, ӨӨРЧЛӨЛТ” БОТЬ II: Усны нөөц, түүний хамгаалалт, зохистой ашиглалт.* Улаанбаатар: Байгаль орчин, аялал жуулчлалын яам [In Mongolian].
- Energy Regulatory Commission (ERC) (2019). *Interview with Mr A.Tleykhan on the possibility to increase the installed capacity in low cost.* Available at http://erc.gov.mn/web/mn/print/337?date=true (Accessed 28 May 2021).
- Ministry of Energy (MOE) (2021). *Statistics on Energy performances*. Available at http://admin.erc.gov.mn/uploads/files/statisticseng.pdf (Accessed 18 September 2021).
- National Statistical Information Service (2020). *Number of households by electricity source*. Available at https://www.1212.mn/ (Accessed 28 May 2021).
- State Great Khural (2001). *Law of Mongolia on Energy.* Ulaanbaatar: State Great Khural.
- Ministry of Energy (MOE) (2020). *Goals and objectives of the Ministry of Energy*. Available fro http://energy.gov.mn/p/22 (Accessed 28 May 2021).
- Energy Regulatory Commission (ERC) (2021) *Tariffs and prices*. Available at http://erc.gov.mn/web/en/cripg (Accessed 28 May 2021).
- Climate Investment Funds (CIF) (2015). *Scaling-up renewable energy programme (SREP) Investment Plan for Mongolia*. Available at https://www.climateinvestmentfunds.org/sites/cif_enc/files/srep_ip_mongolia_final_14_dec_2015-latest.pdf (Accessed 18 September 2021).
- Хидро Инженеринг & Усны Барилга Байгууламжийн Судалгаа Хөгжлийн Төв (ХИ & УББСХТ) (2019). *Монгол оронд гадаргын усны хуримтлал бий болгох, урсцын тохируулга хийх замаар усны нөөцийг нэмэгдүүлэх “Хөх морь” төслийн тайлан*. Улаанбаатар: Хидро-Инженеринг ХХК. [in Mongolian].
- Badarch, A. & Yondongombo, G. (2021). Data collected by the authors.
- Hydroplan Group (2021). *Mongolia Hydropower Opportunity*. Circulating material for roundtable meeting, Department for International Trade, UK.
- Boldbaatar, B. (2008). *Hydropower catalogue of Mongolia*. National Renewable Energy Centre of Mongolia. [unpublished].
- UNIDO, ICSHP (2013). *World Small Hydropower Development Report 2013.* United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
- UNIDO, ICSHP (2016). *World Small Hydropower Development Report 2016.* United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
- UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019.* United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
- Ministry of Energy (MOE) (2021). *Statistical data for 2020.* Available at http://energy.gov.mn/c/1211-ээс Гаргасан [in Mongolian] (Accessed 28 May 2021).
- State Great Khural (2015). *Comprehensive energy policy of Mongolia (2015-2030).* Available at https://www.legalinfo.mn/law/details/11130 [in Mongolian] (Accessed 28 May 2021).
- Ana-Maria, S. (2017). *Mongolia’s energy sector: Time for a rethink*. European Union: CEE Bankwatch Network.
- Government of Mongolia (2018). *Not-so-long programme on implementation of the comprehensive energy policy (2018-2023).* Ulaanbaatar: Government of Mongolia.
- Government of Mongolia (2017). *National energy efficiency action program of Mongolia (2018-2022).* Ulaanbaatar: Government of Mongolia
- Government of Mongolia (2020). *Mongolia’s Long Term Development Policy — Vision 2050.* Ulaanbaatar: Government of Mongolia.
- State Great Khural (2007). *The Law on Renewable Energy.* Ulaanbaatar: State Great Khural.
- Buted, D. (2016). *High capacity hydropower development in the Western region of Mongolia: PhD thesis.* Ulaanbaatar: MUST publishing.
- Bayasgalan, B., Mijiddorj, R., Gomboluudev, P., Oyunbaatar, D., Bayasgalan, M., Tas, A., Molomjamts, L. (2009). *Climate change and sustaiable livelihood of rural people in Mongolia.* Leusden: The adaptation continuum: groundwork for the future. ETC Foundation.

The Republic of Korea

Seung Oh Lee and Dong Hyun Kim, School of Urban and Civil Engineering, Hongik University

KEY FACTS

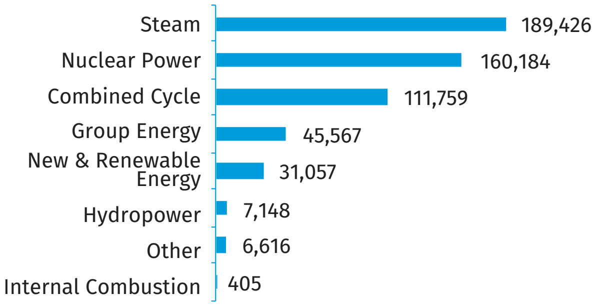
Population	51,829,136 (2020)[1]
Area	100,378 km^2 [2]
Topography	The Korean Peninsula, surrounded by sea on three sides, has a relatively long coastline. Although the altitude is not high, the peninsula has a complex geological nature, with a steep slope and a diverse topography. The average altitude of the Korean Peninsula is 448 metres. The elevation of major mountains, such as Mount Geumgang, Mount Seorak and Mount Odae, is 1,500–1,700 metres above sea level. The highest elevation is Mount Hallasan, located on Jeju Island, the southernmost point of the Korean Peninsula, at 1,947 metres above sea level. The average slope is approximately 5.7° and 77 per cent of mountains are below 400 metres above the sea level.[2]
Climate	The Republic of Korea is located in the mid-latitude temperate climate zone. Winters are cold and dry due to the influence of the continental anticyclone, while summers are hot due to the high temperature and humidity of the North Pacific anticyclone. In spring and autumn there are many sunny and dry days because of the influence of migratory anticyclones. The average annual temperature is 10–15 °C, except for the central mountainous areas and islands. The hottest month is August when temperatures reach 23–26 °C, while the coldest month is January when temperatures range between -6 °C and 3 °C.[3]
Climate Change	Average annual temperature increase for every 10 years of the 20th century amounted to 0.18 °C. The future temperature increase projections in the country match the global average, while the projected increase in precipitation is above the global average. It is expected that extreme weather events will become more frequent.[4,5]
Rain Pattern	Average annual precipitation in the country over the 2010–2019 period was 1,263 mm. There is a large variation in precipitation according to the region and watershed. In the central region, annual precipitation ranges between 1,200 mm and 1,500 mm, in the southern region it is 1,000–1,800 mm. In Jeju Island precipitation ranges between 1,500 mm and 1,900 mm. Seasonally, 50–60 per cent of the annual precipitation torrentially falls during the flood season, which lasts from June to September.[6]
Hydrology	There are five major river basins: the Han River basin, the Geum River basin, the Yeongsan River basin and the Seomjin River basin draining into the Yellow Sea, and the Nakdong River basin draining into the Sea of Japan. Due to the predominantly mountainous terrain of the country, rivers have steep slopes. As a result, during the flood season water flows out very rapidly. On the other hand, during the dry season the amount of runoff is small. As a result, the coefficient of flow rate variation is approximately 90–270. The total amount of water resources in the country is estimated at 132.3 billion m^3/year and the average available water resources are 37.2 billion m^3/year, which is only 28 per cent of the total, with the rest lost due to evapotranspiration and other factors.[7]

ELECTRICITY SECTOR OVERVIEW

In 2020, the total installed capacity of the Republic of Korea was 133,392 MW, of which public utilities accounted for 129,191 MW, or almost 97 per cent. Hydropower accounted for approximately 5 per cent of total installed capacity, or 6,506 MW. New and renewable energy (excluding hydropower) accounted for 18,739 MW, or almost 15 per cent of the total.[8] New and renewable energy in the Republic of Korea is defined as hydropower, including small-scale hydropower, solar power, wind power, bioenergy, marine energy, fuel cell and integrated gasification combined cycle (IGCC).

Annual electricity generation in 2020 totalled approximately 552,160 GWh, with 99.7 per cent, or 550,486 GWh, produced by public utilities. Of the total, steam power plants generated the largest share at over 34 per cent, while hydropower accounted for slightly more than 1 per cent, or 7,148 GWh. New and renewable energy (excluding hydropower) accounted for 31,057 GWh, or less than 6 per cent of total electricity generation (Figure 1).[8]

Figure 1. **Annual Electricity Generation by Source in the Republic of Korea in 2020 (GWh)**



Source: KEPCO[8]

Four administrative districts accounted for approximately 60 per cent of total electricity generation in 2020: Chungnam (21 per cent), Gyeongbuk (16 per cent), Gyeonggi (13 per cent) and Incheon (1 per cent). The leading administrative district in terms of new and renewable energy are Jeonnam, Jeonbuk, Chungna and Gyeongbuk, where approximately 57 per cent of total solar power capacity is located. In terms of hydropower, including small-scale plants, the Gangwon province, with its mountainous terrain and high head, produces the largest amount of electricity, with 1,062 GWh generated in 2020.[8]

Electricity consumption in 2019 totalled 520.5 TWh. The rate of electricity consumption growth reached almost 4 per cent in 2018 compared to the previous year, but in 2019 it decreased to 1 per cent due to mild and cooler weather in winter and summer and the resulting lower demand for heating and cooling.[9] Overall, the electricity consumption trend is being majorly impacted by the recent increase in temperature variability.

After the corporate restructuring in 2001, Korea Electric Power Corporation (KEPCO) was split into six subsidiaries. They now compete with other public companies such as K-water and private companies. The share of private companies in the market increased from 13 per cent in 2009 to 33 per cent in 2019. The installed capacity of KEPCO's six subsidiaries was 83,854 MW in 2020, accounting for 63 per cent of the total. In addition, they accounted for approximately 75 per cent (394,522 GWh) of total electricity generation the same year.[8]

The electricity policy in Korea faced the need for an overall inspection and supplementary measures aimed at ensuring a stable supply and demand of electricity were implemented following the power outage in September 2011. As a result, the sector shifted from the traditional policy focused on expanding supply to a creative and eco-friendly policy focused on demand management.

According to the 9th Basic Plan for Electricity Supply and Demand, it is planned to continuously expand the new and renewable energy generating capacity until 2034 to reach a 30–35 per cent share in the mix by 2040.[10] To accelerate investment in new and renewable energy for the transition to a low-carbon economy and society, the target for solar and wind power was raised from the 12.7 GW to be reached in 2019 to 42.7 GW to be reached by 2025. In addition, in accordance with the 3rd Energy Basic Plan (2019), Renewable Energy Act revision (2019) and the Green New Deal plan (2020), it is planned to reach a total of 77.8 GW of new and renewable energy capacity by 2034 (Table 1).[11]

Table 1. **Planned New and Renewable Energy Capacity by Source in the Republic of Korea by 2034 (MW)**

Category	*Solar power*	*Wind power*	*Hydropower**	*Marine power*	*Bioenergy*	*Fuel cell*	*IGCC*	*Total*
Rated capacity (MW)	45,594	24,874	2,085	256	1,410	3,200	346	77,764
Peak contribution (%)	13.9	3.1	21.6	1.1	44.7	67.7	60.0	–
Capacity factor (MW)	6,338	771	450	3	824	2,166	208	10,760

Source: MTIE[10]

Note: *Small hydropower accounts for approximately 23 per cent.

The Korea Power Exchange (KPX) is in charge of the operation of the electricity market in the country and is responsible for such tasks as pricing and settlement to ensure fair and transparent electricity trade between power generation and sales operators.

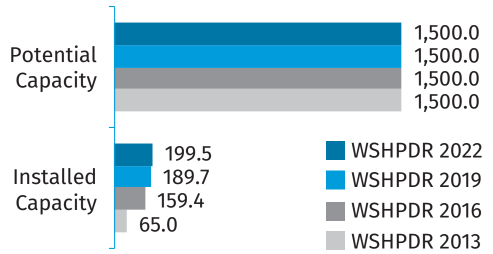
Electricity tariffs in the Republic of Korea are based on a differentiated pricing system according to the purpose of electricity usage: residential, educational, industrial, agricultural, street lighting, public and service, and midnight use. In December 2020, the Ministry of Trade, Energy and Industry (MTIE) and KEPCO announced plans to reform the electricity tariff system, aiming to establish a stronger link between cost fluctuation factors and electricity tariffs, while separately reporting climate and environmental costs. In 2021, an improved residential tariff system was put in place with a provision of financial support for underprivileged consumers. In addition, a seasonal and time-specific differentiated tariff system, similar to the one applied to industrial tariffs, was introduced for residential tariffs. In 2021, residential tariffs ranged from 88.3 KRW/kWh (0.068 USD/kWh) to 285.4 KRW/kWh (0.220 USD/kWh).[12]

SMALL HYDROPOWER SECTOR OVERVIEW

Previously, in accordance with the Alternative Energy Development and Utilization and Supply Promotion Act (1987), hydropower plants with capacity of less than 3 MW were classified as small hydropower (SHP).[13] In 2003 the law was amended to define hydropower plants with capacity of less than 10 MW as SHP. In 2005, the Act on the Promotion of the Development, Use, and Supply of New and Renewable Energy was amended to remove the legal threshold for SHP and unify all hydropower plants regardless of their installed capacity, excluding pumped-storage plants.[14] Currently, the Renewable energy Portfolio Standard (RPS) only supports hydropower plants with capacity of up to 5 MW. Similarly, according to the new and renewable energy facility standards of the Korea Energy Agency, SHP is defined as hydropower of up to 5 MW. For the purposes of comparison with the previous editions of the Report, the present chapter will follow the up to 10 MW definition.

In 2020, there were 169 SHP plants in operation in the Republic of Korea with a combined installed capacity of 199.5 MW (Table 2).[15] The same year they accounted for approximately 9 per cent of total generation, which was approximately 671.3 GWh.[8] The SHP potential is estimated to be 1,500 MW.[16] Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity increased due to the commissioning of new plants. Specifically, in 2018–2019, 14 new projects with a total installed capacity of 9.7 MW were launched (Table 3).[19] At the same time, the estimated potential has remained unchanged (Figure 2).

Figure 2. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in the Republic of Korea (MW)**



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

Note: Data for SHP up to 10 MW.

Table 2. **Installed Small Hydropower Capacities in the Republic of Korea in 2020**

Owner	*Number of SHP plants*	*Capacity (MW)*	*Share (%)*
K-Water	56	84.88	42.54
Private companies	13	39.01	19.55
KRC (Korea Rural Community Corporation)	27	20.66	10.35
KHNP	8	11.27	5.65
Other	65	43.71	21.91
Total	**169**	**199.53**	**100.00**

Source: EPSIS[15]

In the Republic of Korea, various support systems have been put in place to facilitate SHP development. These include announcing the standard price and subsidizing the price difference. In addition, the development of the sector has been facilitated by the continuous decrease of development costs. As a result, the participation in SHP development of such stakeholders as local governments and private companies has greatly increased.

Table 3. **List of Selected Existing Small Hydropower Plants in the Republic of Korea**

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Operator*	*Launch year*
Danyang Submarine	Chungbuk	2.400	N/A	K-water	2019
Sinson Port	N/A	0.150	N/A	N/A	2019
Starlight#1	N/A	0.099	N/A	N/A	2019
Daejung #1	N/A	0.050	N/A	N/A	2019
Daea	N/A	0.015	N/A	N/A	2019
Hydroenergy	N/A	0.009	N/A	N/A	2019
Sohyang	Jeonbuk	3.000	N/A	KRC	2018
Biryong	N/A	0.600	N/A	N/A	2018
Dowon	N/A	0.180	N/A	N/A	2018
Yecheon Yangsu	N/A	0.025	41	N/A	2018
Daesan	N/A	0.019	N/A	N/A	2018
Yanggu Dongmyeon	N/A	0.180	N/A	N/A	2017
Samhan Energy	N/A	2.800	N/A	N/A	N/A
Bohyunsan Dam	N/A	0.170	N/A	N/A	N/A

Source: Lee & Kim[19]

A further three SHP plants were under development as of the moment of writing of this chapter (Table 4).[20] These plants are planned as auxiliary facilities of thermal power plants. Presently, there are no further SHP investment plans to be developed based on preliminary and full feasibility studies.

Table 4. **List of Planned Small Hydropower Projects in the Republic of Korea**

Name	*Location*	*Capacity (MW)*	*Developer*	*Development stage*
Samcheok	Kangwon	N/A	SB Power Co.,Ltd.	Foundation
Goseong High	Gyeongnam	5.0	GG Power Co.,Ltd.	Structure
Sinseocheon	Chungnam	N/A	KOMIPO	To be completed

Source: Korea Power Exchange[20]

Note: Status as of 2021.

The hydropower potential of the Republic of Korea was calculated in a few stages using the data of the Korea Institute of Energy Research and the Electric Power Statistics Information System.[21,22] The total theoretical potential was estimated at 28 GW or 246 TWh/year, the technical potential at 12 GW and 41 TWh/year and the economic potential at 2.5 GW and 8.9 TWh/year. The potential was found to be particularly promising in the provinces of Gyeongnam, Gyeonggi and Gangwon.

RENEWABLE ENERGY POLICY

The key strategy related to climate change in the Republic of Korea is focused on mainstreaming climate change adaptation measures, including improvement of risk adaptation and strengthening of climate change monitoring, forecasting and evaluation.[22] On 28 October, 2020, the President declared the goal to reach carbon neutrality in 2050. Currently, various policies are being implemented to expand the supply of renewable energy, including the Renewable Energy 3020 Implementation Plan (2017) and the 5th New & Renewable Energy Technology Development, Use and Distribution Basic Plan (2020).[23,24] Through the 5th Basic Plan, the share of new and renewable energy in final energy was proposed to reach 13.7 per cent by 2034, with the target for generation raised to 25.8 per cent.

The Alternative Energy Development and Utilization and Supply Promotion Act is intended to promote technology development for, and use and dissemination of, new and renewable energy.[13] Through the law, the Government intends to promote the diversification of energy sources, stable electricity supply, environmentally friendly energy transition and reduction of greenhouse gas emissions. The objective is to contribute to the preservation of the environment, the sound and continuous development of the national economy and the promotion of national welfare. The main contents of the law include the establishment of a basic plan, renewable portfolio standard (RPS), feed-in tariff (FIT) and facility certification. The RPS obliges businesses with power generation facilities of 500 MW or more to supply not less than a certain percentage of electricity from new and renewable energy. In consideration of the Renewable Energy 3020 Implementation Plan, the RPS rate, which is currently at 10 per cent, is intended to be raised after 2023. According to the 4th Renewable Energy Basic Plan, there is also a plan to temporarily introduce FITs to ensure stable profits for businesses and simplify procedures.

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

The existing development targets in the hydropower sector mainly apply to large hydropower with installed capacity above 10 MW. According to the RPS implemented in January 2012, hydropower operators with installed capacity of 5 MW or less can receive Renewable Energy Certificates (RECs) and sell them on the trading market.

COST OF SMALL HYDROPOWER DEVELOPMENT

Based on the available data on several SHP projects, costs per unit vary greatly depending on the project and regardless of the project capacity (Table 5). On average, the cost is estimated at KRW 5,343 million (USD 4.1 million) per MW of installed capacity.[26]

Table 5. **Costs of Selected Small Hydropower Projects in the Republic of Korea**

Name	*Installed capacity (MW)*	*Cost (KRW (USD))*	*Cost per MW (KRW/MW (USD/MW))*
Sancheong	0.40	930,154,000 (714,360)	2,325,385,000 (1,785,900)
Mooju	0.40	388,731,604 (298,547)	971,829,010 (746,400)
SC Green Power Marine	2.75	30,544,210,159 (23,458,010)	11,106,985,512 (8,530,200)
Dongwha Water Purification Plant	0.12	892,973,000 (685,805)	7,441,441,667 (5,715,100)
Daecheong Dam	0.90	4,386,000,000 (3,368,456)	4,873,333,333 (3,742,700)

Source: Korea Power Exchange[26]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

Available sources of financing for SHP projects include Region Supporting Business, Convergence Support Projects, RPS, FITs and Financial Supporting Projects. Region Supporting Business supports a variety of projects to supply new and renewable energy to infrastructure owned or managed by local governments. Under this scheme, between 1996 and 2020, 47 projects received a total of almost KRW 30 billion (USD 23 million) of funding. The scheme also covers SHP projects, mainly at water purification plants and agricultural reservoirs. Convergence Support Projects are financing programmes that cover part of the installation costs of new and renewable energy facilities installed in houses, public buildings and commercial buildings in specific areas. Under this programme, SHP received two grants in 2015, three in 2017 and two in 2018. Finally, the Electrical Industry Foundation Fund offers support for the promotion of renewable energy technology commercialization, with the support provided to hydropower-related projects totalling KWR 53.8 billion (USD 41 million) as of 2019.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The key barriers to SHP development in the Republic of Korea include:

- Limited water resources that fluctuate throughout the year;
- A need for local technology development related to SHP and standardization;
- High dependence on foreign companies;
- Complaints from environmental groups and local residents;
- The burden of initial investment cost.

The key enabling factors for further SHP development are:

- Policy support for new and renewable energy projects, including SHP;

- A range of instruments of financial support;
- Availability of an undeveloped potential.

REFERENCES

1. Korea Statistical Information Service (KOSIS) (2021). *Population, Households and Housing Units*. Available at https://kosis.kr/statHtml/statHtml.do?orgId=101&tblId=DT_1IN1502&vw_cd=MT_ETITLE&list_id=A11_2015_1&scrId=&language=en&seqNo=&lang_mode=en&obj_var_id=&itm_id=&conn_path=MT_ETITLE&path=%252Feng%252FstatisticsList%252FstatisticsListIndex.do (Accessed 28 June 2022).
2. National Geography Information Institute (2019). *The National Atlas of Korea I*. Available at http://nationalatlas.ngii.go.kr/pages/page_1532.php [in Korean] (Accessed 28 June 2022).
3. Korea Meteorological Administration (n.d.). *Korea Climate Characteristics.* Available at https://www.weather.go.kr/w/obs-climate/climate/korea-climate/korea-char.do [in Korean] (Accessed 28 June 2022).
4. Ministry of Environment (n.d.). *Climate Change.* Available at https://eng.me.go.kr/eng/web/index.do?menuId=463#:~:text=Adaptation,becoming%20more%20frequent%20as%20well (Accessed 28 June 2022).
5. National Institute of Meteorological Sciences (n.d.). *Korean Climate Change Outlook Report 2020*
K-water. Available at https://www.water.or.kr/wstatic/easy/easys030101.do?seq=1002&p_group_ seq=53&menu_mode=1 [in Korean] (Accessed 28 June 2022).
6. National Institute of Meteorological Sciences (n.d.). *Precipitation statistics*. Available at https://www.water.or.kr/wstatic/easy/easys030101.do?seq=1002&p_group_seq=53&menu_mode=1 [in Korean] (Accessed 28 June 2022).
7. Ministry Land, Infrastructure and Transport (MTIE) (2016). *Long-Term Comprehensive Water Resources Plan (2010–2020), 3rd version.* Seoul.
8. Korea Electric Power Corporation (KEPCO) (2021). *2020 Statistics of Electric Power in Korea.* Available at https://home.kepco.co.kr/kepco/KO/ntcob/list.do?boardCd=BRD_000099&menuCd=FN05030103 (Accessed 28 June 2022).
9. Ministry of Trade, Industry and Energy (MTIE) (2021). *2020 New & Renewable energy white paper.* Seoul.
10. Ministry of Trade, Industry and Energy (MTIE) (2021). *The 9th Basic Plan for Electricity Supply and Demand (2020–2034).* Available at https://policy.asiapacificenergy.org/sites/default/files/9th%20Basic%20Plan%20for%20Power%20Supply%20and%20Demand%20.pdf [in Korean] (Accessed 28 June 2022).
11. Ministry of Trade, Industry and Energy (MTIE) (2019). *The 3rd Energy Basic Plan.* Seoul.
Hyeon, J. B. (1987) The Present Situation and Outlook on Small Hydropower Development, *Monthly electrical Journal*, 1987(3), pp.18-24.
12. Korea Electric Power Corporation (KEPCO) (n.d.). *Electricity tariffs,* Available at https://cyber.kepco.co.kr/ckepco/front/jsp/CY/E/E/CYEEHP00101.jsp [in Korean] (Accessed 28 June 2022).
13. Ministry of Trade, Industry and Energy (MTIE) (1987). *the Alternative Energy Development and Utilization and Supply Promotion Act.* Seoul.
14. Ministry of Trade, Industry and Energy (MTIE) (2005). *Act on the Promotion of the Development, Use, and Supply of New and Renewable Energy.* Seoul.
15. Electric Power Statistics Information System (EPSIS) (n.d.). Official website. Available at http://epsis.kpx.or.kr/epsis-new/selectMain.do?locale= [in Korean] (Accessed 28 June 2022).
16. UNIDO, ICSHP (2019). *World Small Hydropower Development Report 2019.* United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
17. UNIDO, ICSHP (2013). *World Small Hydropower Development Report 2013.* United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
18. UNIDO, ICSHP (2016). *World Small Hydropower Development Report 2016.* United Nations Industrial Development Organization, Vienna, Austria; International Center on Small Hydro Power, Hangzhou, China. Available at www.unido.org/WSHPDR.
19. Lee, S.O. & Kim, D.H. (2021). Data provided by the authors.
20. Korea Power Exchange (2021). *Current Status of Power Plant Construction Project (First quarter of 2021).* Seoul.
21. Korea Institute of Energy Research (KIER) (2017). *New-Renewable Energy Resource Map Upgrade and Market Potential Analysis.* Seoul.
22. Jung, S. E., Kim, J. Y., Kim, Y. H. & Kim, H. S. (2018). Case Study: Assessment of Small Hydropower Potential Using Runoff Measurements, *Journal of the Korean Solar Energy Society, 38*(4), 43-54.
23. Associated Ministries (2020) *The 3rd National Climate Change Adaptation Measures (2021–2025).* Seoul.
24. Ministry of Trade, Industry and Energy (2017) *Renewable Energy 3020 Implementation Plan.* Seoul.
25. Ministry of Trade, Industry and Energy (2020) *5th New & Renewable Energy Technology Development, Use and Distribution Basic Plan.* Seoul.
26. Korea Power Exchange (n.d.). *Detailed Status of Power Plants in 2019*. Available at http://epsis.kpx.or.kr/epsisnew/selectMain.do?locale= [in Korean] (Accessed 28 June 2022).

Contributing organizations

University Politehnica of Bucharest UPB 1818

Punjab Power Development Board
Energy Department

REESSA CONSULTING
ENERGY STORAGE

Samfunnsbedriftene
Energi

SEDE
CONSULTING

SMEC
Member of the Surbana Jurong Group

ENGINEERING GENERAL
CONSULTANTS
EGC (PVT.) LTD.

Universidad Tecnológica de Panamá 1981

Национальная Академия наук Республики Таджикистан
тадж. Академияи миллии илмҳои Ҷумҳурии Тоҷикистон

SGP The GEF Small Grants Programme
DOMINICAN REPUBLIC

gef

UNDP

USP
THE UNIVERSITY OF THE
SOUTH PACIFIC

UCL
THE BARTLETT
ENERGY INSTITUTE

Universidad Central "Marta Abreu" de Las Villas · Santa Clara · 1948

UNIVERSIDAD DE
MURCIA

Universidad de Oriente
Ciencia y Conciencia
Santiago de Cuba

UniKL
UNIVERSITI
KUALA LUMPUR

UTM
UNIVERSITI TEKNOLOGI MALAYSIA

UNIVERSITY
OF ARCHITECTURE
CIVIL ENGINEERING
AND GEODESY

UNIVERSITY
OF LATVIA

UCG

Université des Sciences et de la Technologie d'Oran - Med Boudiaf
USTO MB

MCMXXII
VYTAUTAS MAGNUS
UNIVERSITY

Wasser World

MINISTRY OF ENERGY & POWER DEVELOPMENT
ZIMBABWE

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Vienna International Centre
P.O. Box 300 · 1400 Vienna · Austria
Tel.: (+43-1) 26026-o
E-mail: renewables@unido.org
www.unido.org

INTERNATIONAL CENTER
ON SMALL HYDROPOWER

136 Nanshan Road
Hangzhou · 310002 · P.R.China
Tel.: (+86-571) 87132780
E-mail: report@icshp.org
www.icshp.org