UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

INTERNATIONAL CENTER
ON SMALL HYDROPOWER

World Small Hydropower Development Report 2022

Eastern Europe

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.

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 Europe

Countries: Belarus, Bulgaria, Czech Republic, Hungary, Moldova, Poland, Romania, Russia, Slovakia, Ukraine

INTRODUCTION TO THE REGION

The countries of Eastern Europe include six member states of the European Union (EU) – Bulgaria, the Czech Republic, Hungary, Poland, Romania, and Slovakia, as well as four non-member states – Belarus, Moldova, Russia and Ukraine. Moldova and Ukraine are members of the Energy Community and are taking steps to unify the legislative framework governing their energy sectors with that of the EU. The electricity grids of the EU member states are interconnected through the ENTSO-E network of transmission operators, which also includes parts of the electricity grid of Ukraine. Significant interconnections additionally exist between Ukraine and Moldova, as well as between Russia and Belarus.

The generation of electricity in Eastern Europe is dominated by thermal power and nuclear power, with the latter present in the energy mix of every country in the region with the exception of Poland and Moldova and accounting for the largest share of annual generation in Slovakia, Hungary and Ukraine. Hydropower and other renewable energy sources (RES) play an important supplementary role in Eastern Europe. Wind power and solar power are used widely but account for a relatively small share of total generation. Poland leads the region in wind power capacity and Ukraine has the region's largest solar power capacity. The region's largest electricity producer is Russia, which sources most of its generation from thermal power, nuclear power and hydropower.

Hydropower is present in the energy mix of every country in Eastern Europe, but in most countries in the region its role is secondary to that of other energy sources. Russia is the region's largest hydropower producer by both installed capacity and annual generation, but hydropower is outpaced in the country by thermal and nuclear power in terms of its share of annual generation. In Slovakia, hydropower is the leading energy source in terms of installed capacity, but accounts for a significantly smaller share of generation than nuclear power. The contribution of hydropower to the energy mix of Belarus, Hungary and Moldova is relatively small. An important issue facing hydropower in Eastern Europe is the age of existing dams and hydropower infrastructure, many of which were built decades ago and increasingly carry the risk of leakage or failure.

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

Table 1. **Overview of Eastern Europe**

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)*
Belarus	9	100	100	11,280	38,179	96	400
Bulgaria	7	100	100	12,839	39,466	3,213	3,000
Czech Republic	11	100	100	21,350	81,444	2,265	3,437
Hungary	10	100	100	9,202	34,154	58	219
Moldova	3	100	100	2,999	4,289	62	147
Poland	38	100	100	49,238	152,308	2,356*	2,698
Romania	19	100	100	18,538	53,000	6,642	15,400
Russia	147	100	100	245,313	1,047,000	49,912	207,416
Slovakia	5	100	100	7,716	29,010	2,544	4,871
Ukraine	44	100	100	54,365	153,800	6,300	7,800
Total	-	-	-	**432,840**	-	**73,448**	-

Source: *WSHPDR 2022*[1]

Note: *Includes only public hydropower. 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 most common definition of small hydropower (SHP) in Eastern Europe includes plants of up to 10 MW, and is adhered to by Belarus, the Czech Republic, Romania, Slovakia and Ukraine. In Hungary, the up to 5 MW definition is used. Russia adheres to the up to 30 MW definition for regulatory purposes but occasionally uses the up to 25 MW definition for the purpose of strategic planning and incentivization of hydropower development. There is no official definition of SHP in Bulgaria, Moldova or Poland.

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 Europe (MW)**

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed capacity (≤10 MW)*	*Potential capacity (≤10 MW)*
Belarus	Up to 10 MW	17.3	250.0	17.3	250.0
Bulgaria	N/A	N/A	N/A	494.7	580.7
Czech Republic	Up to 10 MW	353.0	465.0	353.0	465.0
Hungary	Up to 5 MW	17.1	28.0	17.1*	28.0*
Moldova	N/A	N/A	N/A	0.3	7.2
Poland	N/A	N/A	N/A	291.7	1,500.0
Romania	Up to 10 MW	321.0	730.0	321.0	730.0
Russia	Up to 30 MW	852.9	825,844.6	168.4	168.4**
Slovakia	Up to 10 MW	81.6	145.0	81.6	145.0
Ukraine	Up to 10 MW	119.6	280.0	119.6	280.0
Total	-	-	-	**1,864.7**	**4,154.3**

Source: *WSHPDR 2022*[1]

Note: *Based on the local definition of SHP. **Based on installed capacity of SHP up to 10 MW.

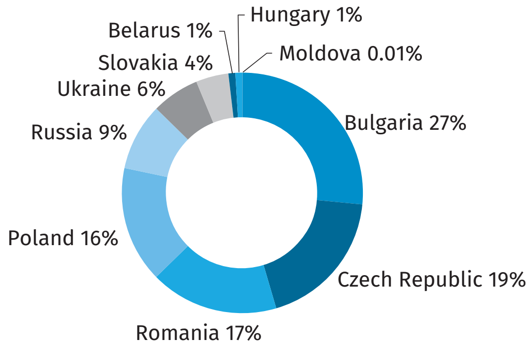
The installed capacity of SHP up to 10 MW in Eastern Europe is 1,864.7 MW, while potential capacity is estimated at 4,154.3 MW. Relative to the *World Small Hydropower Development Report (WSHPDR) 2019*, the total installed capacity decreased by 2 per cent, largely due to a re-assessment of actual capacities of existing SHP plants in Romania by the national energy regulator, although the installed SHP capacities of several other countries increased. The potential capacity of SHP of up to 10 MW in the region decreased by nearly 5 per cent on the basis of more recent assessments of the SHP potential of Slovakia and Ukraine.

SHP has a long history in Eastern Europe. The first plants in the region were constructed in the 1880s, and some continue to operate today after successive refurbishments and upgrades. The first half of the 20th century saw a very large number of plants constructed across the region. Subsequently, some countries in Eastern Europe shifted towards highly centralized electricity generation and many SHP plants were abandoned or fell into disrepair. In the last few decades, some revival of the SHP sector has been observed, which in several countries in the region has been driven largely by private investors seeking to take advantage of liberalized electricity markets and renewable energy subsidies. Some new SHP construction has taken place at previously abandoned sites, which are common across the region. However, the recent proliferation of privately-run SHP plants has generated significant controversy in several countries, particularly in light of increasing seasonal variability in water levels. Additionally, the ageing of existing plants has contributed to decreases in available capacity.

In the last few years, significant construction of new SHP plants has mainly occurred in the Czech Republic, Poland and Ukraine, and to a lesser extent in Belarus, Russia and Romania. However, as the commissioning of new plants has coincided with the decommissioning or re-assessment of available capacity of older plants, cumulative installed capacities of several countries with active SHP development have actually decreased.

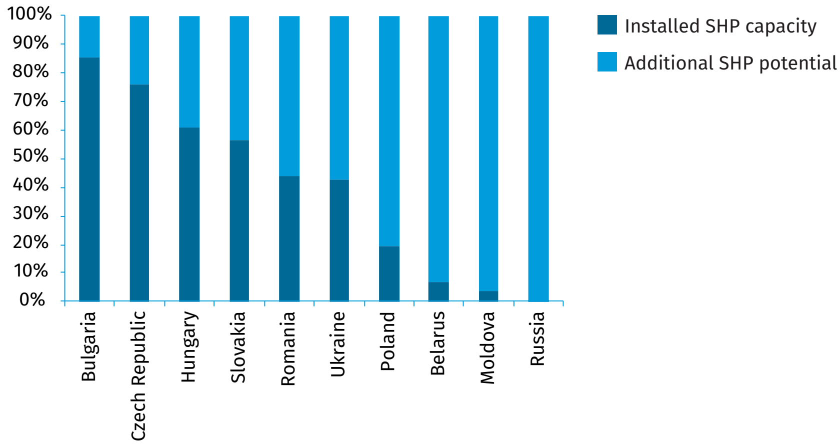
The national share of regional installed SHP capacity by country is displayed in Figure 1, while the share of total national SHP potential utilized by the countries in the region is displayed in Figure 2.

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



Source: *WSHPDR 2022*[1]

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



Source: *WSHPDR 2022*[1]

Note: For SHP of up to 10 MW except in the case of Russia, where the local definition is used due to a lack of data on the potential capacity for SHP of up to 10 MW.

Belarus has an installed capacity of 17.3 MW for SHP of up to 10 MW, provided by 49 plants. Potential capacity is estimated at 250 MW, indicating that approximately 7 per cent has been developed. Although several new mini-hydropower plants have been commissioned over the last few years, the overall installed capacity of the country has not increased as the capacities of previously existing plants have been re-assessed downwards. Thirty-four potential SHP sites have been identified in the country.

The installed capacity for SHP of up to 10 MW in **Bulgaria** is 494.7 MW, while potential capacity is estimated at 580.7 MW, indicating that 85 per cent has been developed. Little new SHP construction has taken place in the country in recent years, although a number of restoration and rehabilitation projects have been carried out on existing plants. There were several ongoing SHP projects in the country as of 2021.

The **Czech Republic** has an installed capacity of 353 MW for SHP of up to 10 MW, while potential capacity is estimated at 465 MW, indicating that 76 per cent has been developed. There are 1,422 SHP plants in the country, of which 953 are micro-scale plants with a cumulative capacity of 38 MW. Such plants make up the bulk of new SHP development in the country, and, while many new plants have been commissioned in recent years, their individual capacities have generally not exceeded several hundred kilowatts. There is a lack of comprehensive information on ongoing or planned SHP projects in the Czech Republic due to a degree of unwillingness on the part of private investors to disclose such information.

The installed capacity for SHP of up to 5 MW in **Hungary** is 17.1 MW provided by 28 plants. Potential capacity for SHP of up to 5 MW is estimated at 28 MW, indicating that 61 per cent has been developed. The estimate of potential capacity in Hungary has been re-assessed on the basis of economic feasibility of potential sites. The most recent SHP plant in the country was commissioned in 2017 and one other SHP plant was recently refurbished. There are no ongoing SHP projects or concrete plans for any additional SHP development.

Moldova has one operational SHP plant with an installed capacity of 0.25 MW. Potential capacity is estimated at 7.2 MW, indicating that nearly 4 per cent has been developed. A large number of formerly operational plants and abandoned SHP sites exist in the country, with as many as 17 plants operational in the 1960s. A significant part of the country's identified potential capacity comes from these abandoned or non-operational plants rather than greenfield sites. However, there are no specific plans or ongoing projects for additional development or refurbishment of SHP in Moldova at this time.

In **Poland**, the installed capacity of SHP of up to 10 MW is 291.7 MW, while potential capacity is estimated at 1,500 MW, indicating that 19 per cent has been developed. SHP development in the country is actively ongoing, with multiple plants commissioned between 2018 and 2020. A very large number of identified potential sites exist in the country, including thousands of historical sites such as former water mills and abandoned hydropower plants that could host potential SHP projects. A number of SHP projects are in the planning stages, to be commissioned in 2023.

The installed capacity of SHP of up to 30 MW in **Russia** is 852.9 MW, while the technically-feasible potential capacity is estimated at 825,845 MW, indicating that less than 1 per cent has been developed. The installed capacity of SHP of up to 10 MW is 168.4 MW, although no reliable estimate of potential capacity for SHP of up to 10 MW is available. Regionally, the North-Western and North Caucasus regions lead the country in installed SHP capacity, while the largest potential capacity is located in the Far Eastern region. Several new SHP plants have been constructed in recent years and several existing plants have been refurbished. Major renovation of approximately 40 SHP plants is planned for 2025–2026.

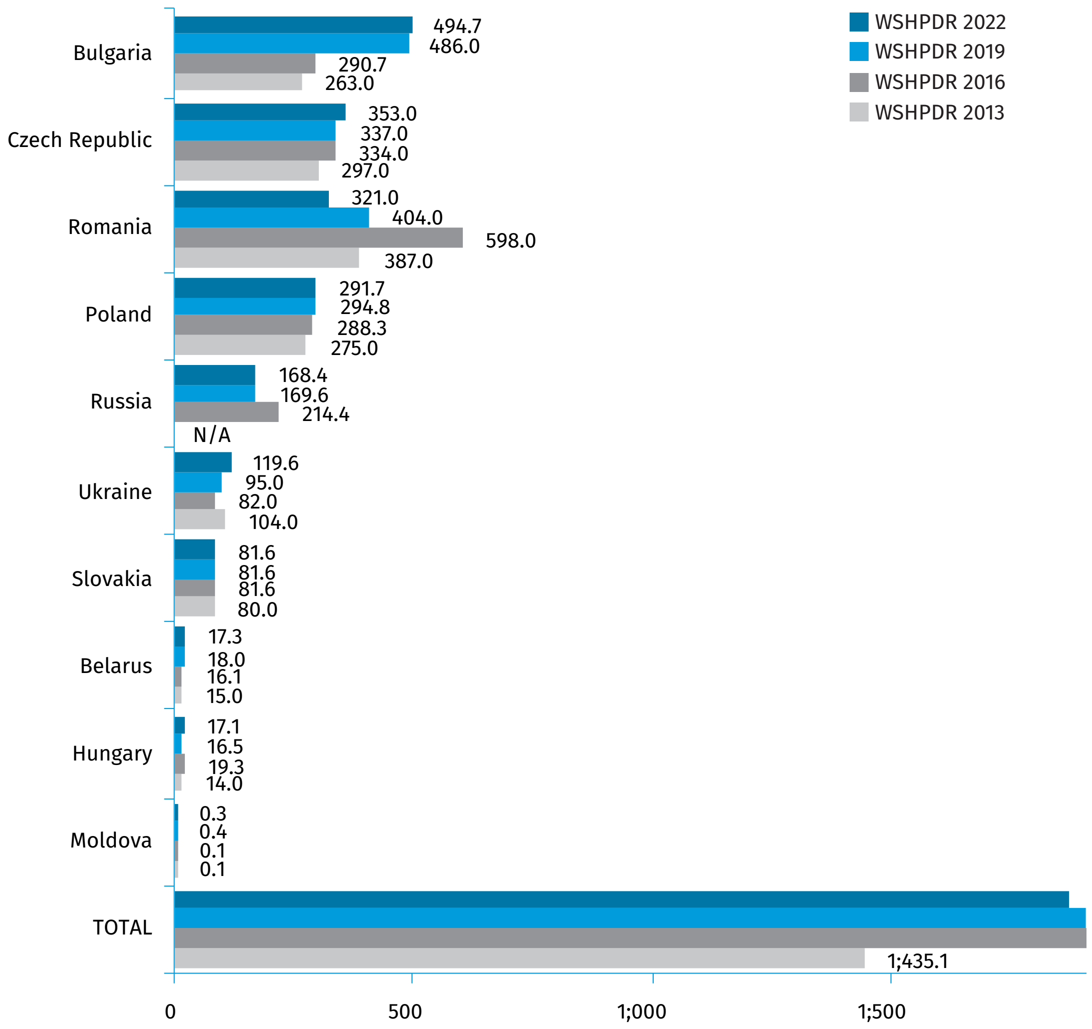
Romania has an installed capacity of 321 MW for SHP of up to 10 MW, provided by 103 plants. Potential capacity is estimated at 730 MW, indicating that approximately 44 per cent has been developed. SHP development in the country is ongoing with several new plants commissioned between 2017 and 2021, although the reported installed capacity of the country has decreased due to a reassessment of the actual capacities of existing plants.

Slovakia has an installed capacity of 81.6 MW for SHP of up to 10 MW, while potential capacity is estimated at 145 MW, indicating that approximately 56 per cent has been developed. There are 217 SHP plants operating across the country. Little SHP development has taken place in Slovakia over the last decade, with the most recent plant commissioned in 2014. An ambitious plan to develop an additional 160 MW of SHP capacity by 2030, proposed in 2011, has stalled due to environmental considerations. A more recent plan published in 2019 envisions a total SHP capacity of 145 MW to be achieved by 2030.

The installed SHP capacity of up to 10 MW in **Ukraine** is 119.6 MW provided by 167 plants. Potential capacity is estimated at 280 MW, reflecting the latest published data and representing a major decrease from previous estimates. These figures indicate that approximately 43 per cent of the total potential has been developed. SHP development in the country has been very active, with 15 new plants commissioned in 2019 alone. However, some of these projects were undertaken with insufficient oversight and have caused concern among locals and environmental activists. There are several ongoing and planned SHP projects in the country.

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

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



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

Climate Change and Small Hydropower

A decrease in annual precipitation across most of the southern basins in Eastern Europe is projected by climate models, but no significant changes are expected in Hungary and in the Czech Republic. A recent study undertaken in Poland concluded that both positive and negative impacts on hydropower in the country are possible, depending on the climate change scenarios considered. Uneven precipitation distribution with wetter winters and more frequent droughts in the summer may negatively affect the viability of existing SHP plants and complicate planning and development of new SHP projects. In Ukraine and Moldova, additional river runoff regulations affecting farmland are expected to increase water use competition between SHP and irrigation. The SHP potential of Russia will likely benefit from climate change, but heavier precipitation is also expected to increase the risk of dam erosion and flooding of dam infrastructure.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The main obstacles to SHP development in **Belarus** include the fact that the country's current and near-term electricity needs are met by the recent commissioning of new nuclear power capacities and the low hydropower potential in certain parts of the country due to the prevailing topography. However, potential opportunities for SHP development include the large number of formerly operational sites and the availability of detailed studies of SHP potential and development costs.

The majority of assessed SHP potential in **Bulgaria** is considered to be developed, and a lack of publicly available hydrological data hinders the planning of new projects. Additionally, regulatory barriers limit the construction of SHP in many potential locations and the country's local technical capacities in hydropower have declined over the last few decades. At the same time, SHP development in the country enjoys strong support in the form of feed-in tariffs (FITs) and can access a variety of funding opportunities from private commercial entities, public-private partnerships and international programmes.

Barriers to SHP development in the **Czech Republic** include regulatory obstacles, high operation and maintenance cost, a focus on other energy sources in strategic planning as well as political and social pushback against SHP. While some undeveloped potential remains in the county, the most promising sites have largely been developed. However, the SHP sector in the country benefits from FITs and other forms of support. Alongside the remaining undeveloped potential, there are opportunities in the refurbishment of existing plants.

Further SHP development in **Hungary** is unlikely in the near term as the country has prioritized the development of additional nuclear power capacity as well as that of non-hydropower RES, in particular solar power. Additionally, the most promising SHP sites in Hungary have already been developed. The main enabler of additional SHP development in the country is the remaining untapped potential.

The main barriers to additional SHP development in **Moldova** are a lack of financing as well as a lack of local technical expertise and manufacturing capacity in the SHP sector, requiring that most necessary equipment be imported at high cost. At the same time, there is substantial institutional support for SHP development in the country, including a comprehensive legal framework, subsidies and other support schemes. Demand for additional electricity in the country is high and could act as an additional incentive for investment in SHP.

Barriers to SHP development in **Poland** include regulatory and administrative barriers, high costs of operation (particularly with the adoption of new water pricing policies in 2018) and insufficient length of available support periods. Enablers include a robust FIT and feed-in premium (FIP) framework and a large number of identified potential sites on existing infrastructure.

Romania lacks support schemes for SHP and other RES, which alongside the high cost of water for power generation and complex licensing procedures discourages investors in the SHP sector. There is a lack of recent data on the country's SHP potential, and opposition to SHP development from environmental groups has posed an additional obstacle. The main enabler of SHP development in Romania is the country's significant untapped SHP potential.

In **Russia**, a lack of targeted state support for SHP, excessive regulatory requirements and a shortage of up-to-date scientific data on potential sites all act as constraints on SHP development. While the country has massive undeveloped SHP potential, much of it is located in hard-to-access areas with low population densities, making SHP projects in such locations economically unfeasible in most cases. However, support programmes do exist for small-scale power generation regardless of the energy source, which also apply to SHP, as well as support for RES facilities. The SHP sector in Russia is mature and relies on extensive local technical expertise and manufacturing capacity.

The main barrier to SHP development in **Slovakia** has been the concern over the impact of SHP on the environment and particularly on the ecological sustainability of rivers. Additional constraints include competition with other RES that generate a faster return on investment, as well as lengthy administrative procedures required for the approval of new projects. On the other hand, the SHP sector in the country benefits from several support schemes including FITs and green auctions, considerable potential remains untapped and there are specific plans for the expansion of the country's SHP capacity over the next decade.

Major barriers to SHP development in **Ukraine** include the limited hydropower potential in most parts of the country and increasing concerns over the environmental impact of SHP. Additionally, plant capacity factors have been steadily decreasing over the last decade due to falling water levels, putting into question the feasibility of some new and existing projects. One important enabler of SHP development in the country is the potential construction of SHP facilities on existing water supply infrastructure and outflow from industrial sites. Several such projects have already been realized and are generally well-received by the public.

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.

Belarus

Anastasiya Timashenok, Ministry of Energy of the Republic of Belarus

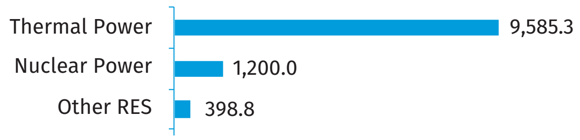
KEY FACTS

Population	9,349,645 (2021)[1]
Area	207,600 km²[2]
Topography	The Republic of Belarus is a landlocked country. It is relatively flat and contains large tracts of marshy land. The highlands of the Belarusian Range run from the north-east to the south-west, with the highest peak at Mount Dzyarzhynskaya near Minsk, at 345 metres. Approximately 40 per cent of Belarus is covered by forest.[3]
Climate	The country lies in the transitional zone between the continental and maritime climates. In the winter, the climate is cold with average temperatures in January ranging from -4.5 °C in the south-west (Brest) to -8 °C in the north-east (Vitebsk). In the summer, the climate is cool and moist, with the highest temperatures in July at 18.5 °C.[4]
Climate Change	In the 20 years between 1989 and 2019, Belarus experienced 17 years with the highest average annual temperature since records began in 1881, with the average annual temperature exceeding the climatic norm by 1.3 °C.[5] As a consequence of rising temperatures, the northernmost agroclimatic region of Belarus has all but disappeared, while a new agroclimatic region has formed in the southern part of the country. Meanwhile, the increased unevenness of precipitation together with rising temperatures have also led to a two-fold increase in drought conditions in various parts of the country since 1992 relative to previous years, which has severely impacted agriculture. Extreme hydrometeorological phenomena such as unseasonal frosts, hailstorms, severe rainstorms and snowstorms as well as exceptionally strong winds have also increased in severity if not in frequency.[5,6] Long-term climate change models predict an increase in average monthly temperatures in Belarus of 0.6-1.9 °C over the period of 2010–2039 relative to the baseline period 1961-1990 and a further increase of 1.0-2.9 °C during the subsequent period of 2040–2069. Patterns of precipitation are also predicted to continue to shift, with the southern regions experiencing occasional droughts and the northern regions an excess of rainfall.[6]
Rain Pattern	Belarus receives an average annual precipitation of 600–700 mm, with extremes of 300 mm in dry years and 1,000 mm in humid years. Most precipitation falls during the warm season.[4]
Hydrology	There are approximately 20,800 rivers with a total length of 90,600 km, along with 10,800 lakes, 153 water reservoirs and 1,500 ponds. The country is divided into the Black Sea and the Baltic Sea basins. The former includes the Dnieper, Sozh and Pripyat Rivers and collects approximately 55 per cent of the runoff in the country. The latter includes the Western Dvina, Neman, Vilia and Western Bug Rivers and collects approximately 45 per cent of the runoff.[7]

ELECTRICITY SECTOR OVERVIEW

The total installed capacity in the Republic of Belarus amounted to approximately 10,074.0 MW in 2020 and increased to 11,280.0 MW by July 2021, following the commissioning of the first reactor of the Belarussian Nuclear Power Plant (Ostrovets NPP). Thermal power plants provided 9,585.3 MW (85 per cent) of the total capacity in 2021, including 8,800.2 MW of traditional thermal power and thermal power plants utilizing steam turbines as well as 785.1 MW provided by block power plants fuelled by non-renewable energy sources; nuclear power provided 1,200.0 MW (11 per cent); non-hydropower renewable energy sources (RES) provided 398.8 MW (4 per cent); and hydropower provided 95.9 MW (1 per cent) (Figure 1).[8,9,10]

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

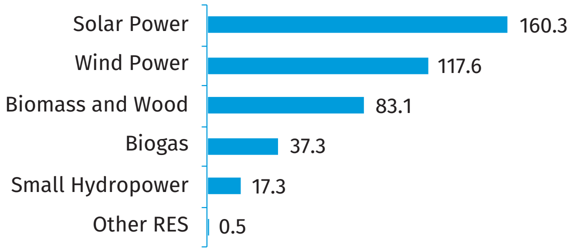


Source: Belenergo,[8] MoE,[9] Timashenok[10]

The total installed capacity of all RES in Belarus, including small hydropower (SHP) but excluding large hydropower, amounted to 416.1 MW in 2021. Of this total, solar power provided 160.3 MW (39 per cent), wind power 117.6 MW (28 per cent), biomass and wood 83.1 MW (20 per cent), biogas 37.3

MW (9 per cent), small hydropower 17.3 MW (4 per cent), and other RES 0.5 MW (less than 1 per cent) (Figure 2).[9,10]

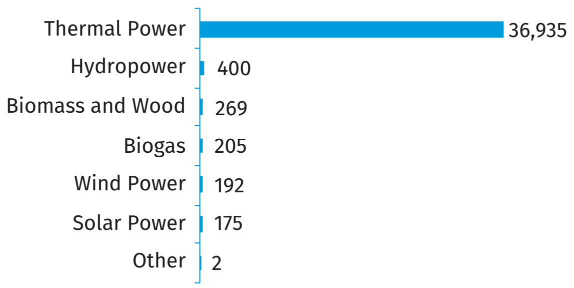
Figure 2. **Installed Renewable Energy Capacity by Source in Belarus in 2021 (MW)**



Source: Timashenok[10]

In 2020, total annual generation amounted to approximately 38,179 GWh, decreasing from 40,451 GWh in 2019. Thermal power from non-renewable sources provided 36,935 GWh (97 per cent) of the total in 2020, hydropower provided 400 GWh (1 per cent) and non-hydropower RES provided a combined total of 844 GWh (2 per cent), including 269 GWh from biomass and wood fuel, 205 GWh from biogas, 192 GWh from wind power, and 175 GWh from solar power, with other RES providing an additional 2 GWh (Figure 3).[10,11] Energy consumption in 2019 reached 38,113 GWh, and remained on roughly the same level in 2020 (approximately 38,020 GWh). Imports of electricity in 2019 equalled 32 GWh, while exports reached 2,370 GWh, representing a significant increase over previous years and continuing a shift from net energy imports to net electricity exports first observed in 2018. Imports in 2020 increased to 154 GWh, while exports decreased to 653 GWh.[8,10,11] The electrification rate in Belarus is 100 per cent.[12]

Figure 3. **Annual Electricity Generation by Source in Belarus in 2020 (GWh)**



Source: Timashenok[10]

The major player in the electricity sector in Belarus is the State Production Association Belenergo (SPA Belenergo), a state-owned company. In 2020 it operated 67 plants totalling 88 per cent (8,897.3 MW) of the installed capacity of Belarus and was responsible for 89 per cent (35.9 TWh) of all electricity generation in 2019 and 88 per cent (33.7 TWh) in 2020.[8,10] Belenergo is subordinate to the Ministry of Energy, with its objectives including the generation, transmission, distribution and sale of both electricity and heat. Belenergo works through a number of subsidiaries, which include six regional distribution companies and the Ostovets NPP. It additionally provides technical support and plays a leading role in initiating energy investment projects.[10]

Power plants utilizing RES in Belarus are primarily operated by private entities. The Ministry of Energy and Belenergo both implement measures to guarantee a connection of these privately owned plants to the state power grid as well as to guarantee the purchase by the state of all electricity generated by RES.[10,13]

The most significant recent development in the electricity sector of Belarus is the construction and commissioning of the Ostrovets NPP, the first nuclear power plant in Belarus, consisting of two reactors of 1,200 MW each. Construction of the plant is being carried out jointly with the Russian state company Atomstroyexport (ASE). The first reactor was connected to the grid in November 2020 and was granted an operating licence and put into commercial operation on 2 June 2021. The second reactor is expected to be commissioned in 2022. Once operating at full capacity, the plant is expected to generate 18 TWh annually, replacing 4.5 billion m^3 of natural gas per year.[10,14,15]

Electricity tariffs in Belarus can be divided into two general categories: single-rate and differentiated. The differentiated tariff rate depends on the time period of electricity consumption (minimum or maximum load). Additionally, tariffs for households are differentiated by the kind of stove installed on the property (gas or electric). Generally, prices for households are significantly lower than for other types of consumers (Table 1).

Table 1. **Electricity Tariffs in Belarus as of 01 January 2021**

Type of user	*Tariff in BYN/kWh (USD/kWh)*
Households	0.0374 – 0.4184 (0.0150-0.1600)
Industrial consumers: Basic fee — for capacity (for 1 month) Extra charge — for energy	26.7134 (10.3584) 0.2259-0.3297 (0.0876 – 0.1278)
Street lighting	0.3218 (0.1248)
Agricultural consumers	0.1406 – 0.2695 (0.0545 – 0.1045)
Transport	0.2606 (0.1011)
Charging stations for electric vehicles and hybrid electric vehicles	0.1269 – 0.1817 (0.0492 – 0.0705)

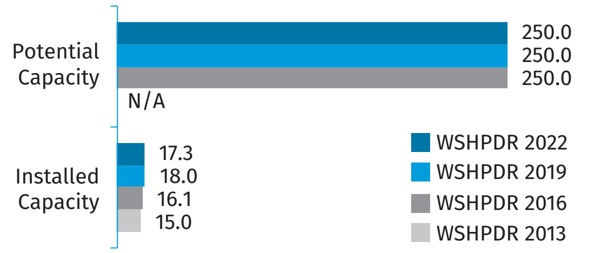
Source: Council of Ministers of Belarus,[16] Energosbyt[17]

Note: basic fee for industrial consumers charged per kW of connected capacity, rather than kWh.

SMALL HYDROPOWER SECTOR OVERVIEW

The definition of SHP in Belarus is up to 10 MW. As of 2021, there were 49 SHP plants operating in the country with a total installed capacity of 17.3 MW. SPA Belenergo operates 21 SHP plants with a total installed capacity of approximately 9.5 MW, while the remaining plants are operated by local public entities and private companies. All operational SHP plants are connected to the national grid.[10,18] A list of the 20 most recently commissioned SHP plants is displayed in Table 2. Relative to the *World Small Hydropower Development Report* (*WSHPDR) 2019*, the installed capacity of SHP has decreased by approximately 4 per cent despite several additional SHP plants being commissioned since its publication, due to more accurate data becoming available. The estimate of economically feasible SHP potential remains 250 MW, as no new assessments have taken place since 2010 (Figure 4).[19]

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



Source: Timashenok,[10] Belnergo,[18] *WSHPDR 2019*,[19] *WSHPDR 2013*,[20] *WSHPDR 2016*[21]

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

Name	*Location*	*Capacity (MW)*	*Plant type*	*Operator*	*Launch year*
Sakovschina mini-HPP	Western Berezina River	0.225	Reservoir	Ministry of Agriculture and Food	1955/ 2008
Klyastitskaya SHPP	Nishya River	0.520	Reservoir	Belenergo	2008
Duboy mini-HPP	Dnieper-Bug Canal	0.330	Reservoir	Dnieper-Bug Water Route	2008
Voykovskaya mini-HPP	Dvinosa River	0.080	Reservoir	Minskmeliovodkhoz	2008
Kobrin mini-HPP	Dnieper-Bug Canal	0.200	Reservoir	Dnieper-Bug Water Route	2009
Sychevichskaya HPP	Rybchanka River	0.110	Reservoir	Minskmeliovodkhoz	2009
Zhodinskaya HPP	Pleesa River	0.030	Reservoir	Minskmeliovodkhoz	2009
Chizhovskaya HPP	Svisloch River (CHP-3 reservoir)	0.320	Reservoir	"Small Energy" LLC	2010
Drozdy HPP	Svisloch River (Drozdy reservoir)	0.300	Reservoir	"Small Energy" LLC	2010
Zaluz'ye HPP	Dnieper-Bug Canal	0.180	Reservoir	Dnieper-Bug Water Route	2011
Gavia HPP	Gavia River	0.190	Reservoir	"Umyastovsky" Cooperative	2011
Novosady SHHP	Dnieper-Bug Canal	0.223	Reservoir	Dnieper-Bug Water Route	2012
SHPP in Alexandria	Ulyanovka River	0.055	Reservoir	OJSC "Alexandriyskoe"	2012
Quarry "Gralevo"	Water intake of "Gralevo" quarry	0.700	Reservoir	JSC "Dolomit"	2014
SHPP "Stakhovo"	Dnieper-Bug Canal	0.692	Reservoir	Dnieper-Bug Water Route	2016
SHPP at "Verkhnee" reservoir	Lososyanka River	0.060	Reservoir	Grodnozhilstroy OJSC	2016
Slonimskaya mini-HPP	Issa River	0.200	Reservoir	HydroPark Ltd.	2017
Dobrush HPP	Iput River	0.450	N/A	Dobgidroinvest Ltd.	2019
Mnyuta HPP	Mnyuta River	0.160	Reservoir	HydroPark Ltd.	2019
Krupki SHPP	Bobr River	0.100	Reservoir	DobHydroInvest Ltd.	2020

Source: Timashenok,[10] Belenergo,[18] Batskalevich[22]

The development of SHP in Belarus has followed a pattern similar to that in other post- Soviet states. A large number of SHP plants were constructed in the immediate post-war period, with as many as 180 SHP plants operating in the country at the end of the 1950s.[23] However, most of these were decommissioned or abandoned in the subsequent decades as priorities shifted to large-scale power production and consumers previously dependent on electricity from SHP plants were gradually connected to the national grid.[24] During the period of 1990–2000s, a number of these plants were refurbished and put back into operation, while some of those still in operation were upgraded with new turbines.

In the last decade, little if any SHP development has taken place in Belarus and additional SHP development is not a priority for Belenergo at the moment. This position is tied in part to the construction and recent commissioning of the Ostrovets NPP.[10] Plans in 2010 included the construction of seven new, and the refurbishment of five existing, mini- and small hydropower plants, with a total potential capacity of 3.2 MW. However, the extent to which these plans have been realized is unclear.[23] One study conducted in 2011 surveyed potential new hydropower sites in Belarus and identified 34 SHP sites on 24 rivers and streams, with a total potential capacity of 72.85 MW, that can be considered environmentally and economically feasible for development. The study additionally estimated approximate development costs of each site per installed kW. A list of selected identified sites is displayed in Table 3.[25]

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

Location	*Distance from river mouth (km)*	*Head (m)*	*Potential capacity (MW)*	*Area of reservoir (km²)*	*Cost (USD/kW)*
Dnepr River 1	1,410.0	5.6	9.21	115.3	2,742
Vilia River 1	279.2	9.7	8.89	11.0	549
Dvina River	8.5	9.7	7.75	8.4	623
Dnepr River 2	1,671.3	4.7	5.52	5.3	681
Berezina River	227.8	6.0	5.03	74.8	2,512

Source: Kalinin & Alferovich[25]

Table 4. **Tariffs for SHP plants**

Category/Period of Operation	*Price in BYN/kWh (USD/kWh)*
First 10 years after commissioning-	
Plants up to 300 kW:	0.244 (0.097)
Plants 301 kW - 2 MW:	0.229 (0.092)
Plants over 2 MW:	0.215 (0.086)
Between 10 and 20 years after commissioning:	0.129 (0.052)
More than 20 years after commissioning:	0.129 (0.052)

Source: Energosbyt,[17] MART[30]

Note: Tariffs apply to plants issued quota allotments between 1 November 2019 and 31 December 2020 and commissioned between 1 January 2020 and 31 December 2023.[30]

RENEWABLE ENERGY POLICY

The main principles guiding the development of RES in Belarus in recent years were outlined in the Law of the Government of the Republic of Belarus of December 27, 2010 No. 204-Z on Renewable Energy Sources. The primary objective of the act was to diversify the sources of electricity generation by 2020. Stipulations of the law, which remains in force, include guaranteeing the connection of electricity producers from RES to the national grid as well as the purchase of all electricity produced from RES by the state, while obligating the producers to meet certain technical requirements and to cover the costs of connection.[13]

In 2011, Resolution No. 836 of the Council of Ministers established the procedure for running the state cadastre of RES. In 2015, several additional legal acts related to RES entered into force, including Decree of the President of the Republic of Belarus No. 209 of 18 May 2015 on the Use of Renewable Energy Sources (later replaced by Decree of the President of the Republic of Belarus No. 357 of 24 September 2019) and Resolution of the Government of the Republic of Belarus No. 662 of 6 August 2015, which were called to regulate the procedure of the establishment and allocation of quotas for RES power plants.[26,27,28,29]

Tariffs paid to producers of electricity from RES by the state purchaser are set by the Ministry of Antimonopoly Regulation and Trade (MART), the most current resolution being MART Resolution No. 73 from 3 September 2018, along with its revisions in Resolutions No. 70 from 26 August 2019, No. 87 from 31 October 2019 and No. 62 from 24 September 2020. Tariffs are allocated according to the RES type, date of quota allocation and date of commissioning of the plant. A coefficient allocated based on these factors is applied to the baseline price, set to equal the current cost of electricity for industrial consumers with connected capacity of below 750 kVA, to form the final tariff.[30] Table 4 displays the current tariffs for newly-constructed SHP plants.

COST OF SMALL HYDROPOWER DEVELOPMENT

Prior studies have identified a range of sites in Belarus suitable for the construction of new SHP plants, with an estimated cost range of between 558 and 2,742 USD/kW. The SPA Belenergo programme for the construction and refurbishment of hydropower plants until 2020, adopted in 2003, provided for the construction of new SHP plants of no less than 100 kW capacity and with a cost of no more than 2,000 USD/kW.[25] Other assessments have set an upper limit of 2,750 USD/kW as economically feasible in the context of Belarus.[24]

New SHP plants constructed in Belarus in the last 15 years have carried price tags somewhat exceeding the upper limits discussed above. The Soligorsk SHP plant on the River Sluch' with an installed capacity of 150 kW, commissioned in 2007, cost 1.24 billion BYN (576,744 USD), or 8.30 million BYN/kW (3,845 USD/kW).[24] Meanwhile, the total cost of the Stakhovo SHP plant on the Dnieper-Bug Canal with an installed capacity of 630 kW, commissioned in 2015 and equipped with turbines manufactured in Austria, reached approximately 33 billion BYN (2,062,500 USD), or approximately 52 million BYN/kW (3,274 USD/kW).[31]

EFFECT OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Shifts in the distribution of precipitation across Belarus, forecast by climate models for the period of 2010–2069, may negatively affect the viability of SHP plants operating in the southern part of the country, where a decrease in precipitation is expected in the coming decades.[6] Additionally, regional changes in the distribution of runoff in the transboundary Neman (Niemen) River basin forecast for the period of 2021–2050 may see the part of the basin within the boundaries of Belarus experiencing an up to 20 per cent decline in runoff relative to the 1961–1985 baseline period. Conversely, the sections located in Russia and Lithuania may experience a corresponding 20 per cent increase.[32] Such a substantial decline in runoff can be expected to negatively impact existing SHP plants and undermine the viability of future SHP development on rivers located in the basin, including the Neman but also the Vilia, Strana, and Shyara Rivers.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The primary obstacles for the further development of SHP in Belarus include the following:

- The electricity needs of the country being largely met by existing capacities and development of future capacity targeted towards export, with efforts to reduce the dependence of Belarus on fossil fuel imports prioritizing nuclear power development;
- Low hydropower potential in the northern and central parts of the country due to the prevailing topography;
- Cost of new SHP development often in excess of what is deemed economically appropriate for Belarus;
- All other RES receiving higher initiation incentives in the RES tariff pricing structure than SHP;
- Threats to the viability of SHP in certain parts of the country due to climate change.

Possible enablers for SHP development in Belarus include the existence of a large number of decommissioned SHP plants in various stages of disrepair, some of which could potentially be refurbished, as well as the publication of prior studies mapping SHP potential and cost.

REFERENCES

1. National Statistical Committee of the Republic of Belarus (2021). *Population by sex and age*. Available at https://www.belstat.gov.by/en/ofitsialnaya-statistika/Demographic-and-social-statistics/population-and-migration/population/ (Accessed 04 June 2021).
2. Food and Agriculture Organization of the United Nations (FAO) (2015). *Country profile – Belarus*. Available at http://www.fao.org/3/ca0325en/CA0325EN.pdf (Accessed 04 June 2021).
3. Nations Encyclopedia (n.d.). *Belarus*. Available at https://www.nationsencyclopedia.com/Europe/Belarus.html (Accessed 04 June 2021).
4. World Bank Group (n.d.). *Belarus. Climate Data – Historical*. Climate Change Knowledge Portal. Available at https://climateknowledgeportal.worldbank.org/country/belarus/climate-data-historical (Accessed 04 June 2021).
5. United Nations Development Programme (UNDP) in Belarus. *What is happening with climate change in Belarus?* Available at https://www.by.undp.org/content/belarus/ru/home/presscenter/blog/climate_change_belarus_blog.html [in Russian] (Accessed 04 June 2021).
6. Belarus Red Cross (2015). *National report: vulnerability and adaptation to climate change in Belarus*. Available at http://www.minpriroda.gov.by/uploads/files/Otsenka-ujazvimosti-Belarusi-Rus.pdf [in Russian] (Accessed 04 June 2021).
7. Centre for Climate Adaptation. (2015). *Fresh water resources Belarus*. Climate Change Post. Available at http://www.climateadaptation.eu/belarus/fresh-water-resources/ (Accessed 04 June 2021).
8. Belenergo (2021). *Main indicators*. Available at https://www.energo.by/content/deyatelnost-obedineniya/osnovnye-pokazateli/ (Accessed 04 June 2021).
9. Ministry of Energy (MoE) (2020). *Capacity of RES installations to increase by a factor of 1.5 by 2025*. Official Website of the Ministry of Energy of the Republic of Belarus. Available at https://www.minenergo.gov.by/press/aktualno/moshchnost-ustanovok-vie-v-belarusi-k-2025-godu-uvelichitsya-v-1-5-raza/ [in Russian] (Accessed 04 June 2021).
10. Timashenok, A. (2021). Author's personal research and communication with stakeholders (unpublished).
11. National Statistical Committee of the Republic of Belarus (2019). *Electric energy balance*. Available at https://www.belstat.gov.by/upload-belstat/upload-belstat-excel/Oficial_statistika/Godovwe/Balans_el_energii-19.xlsx (Accessed 04 June 2021).
12. World Bank (n.d.). *Access to electricity (% of population) – Belarus*. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=BY (Accessed 05 June 2021).
13. National Assembly of Belarus (2010). *Law of the Republic of Belarus No. 204-Z of 27 December 2010, on Renewable Energy Sources*. Available at https://www.windpower.by/files/files/en/law-204-en.doc (Accessed 05 June 2021).
14. World Nuclear News (2020). *Belarus approves power start-up of Ostrovets unit*. Available at https://www.world-nuclear-news.org/Articles/Belarus-approves-power-start-up-of-Ostrovets-unit (Accessed 05 June 2021).
15. Ministry of Emergency Situations of Belarus (MChS) (2021). *Belarusian NPP granted licence for the operation of power unit No. 1*. Available at https://mchs.gov.by/glavnoe/353894/ [in Russian] (Accessed 05 June 2021).
16. Council of Ministers of Belarus (2020). *Decision of the Council of Ministers of the Republic of Belarus No. 795 of 31 December 2020, on Amendments to the Decision of the Council of Ministers of the Republic of Belarus No. 1166 of 30 December 2013*. National online law portal of the Republic of Belarus. Available at https://pravo.by/upload/docs/op/C22000795_1609880400.pdf [in Russian] (Accessed 05 June 2021).
17. Energosbyt (2021). *Tariffs for electrical energy for legal entities and individual entrepreneurs (as of 01.01.2021)*. Available at https://www.energosbyt.by/ru/info-potrebitelyam/ur-l/tarify/tarify-elektro [in Russian] (Accessed 05 June 2021).
18. Belenergo (2021). *Installed capacity (as of 01.01.2021)*. Available at https://www.energo.by/content/deyatelnost-obedineniya/osnovnye-pokazateli/ustanovlennaya-moshchnost/ (Accessed 06 June 2021).
19. 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.

20. 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.
21. 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.
22. Batskalevich, A.I. (2017). *Pilot GIS project "Hydropower plants of Belarus".* Available at https://www.arcgis.com/apps/MapTour/index.html?appid=6efb82417d934a66af08d0f075d7c2f1 [in Russian] (Accessed 06 June 2021).
23. Renewable Energy Association (n.d.). *Hydropower.* Available at http://www.energy-aven.org/belarus/hydro/ [in Russian] (Accessed 06 June 2021).
24. Belarus Today (2007). *Rivers will also need to exert power*. Available at https://www.sb.by/articles/pridetsya-na-pryachsya-i-rekam.html [in Russian] (Accessed 06 June 2021).
25. Kalinin, M.Yu., & Alferovich, V.N. (2011). *Hydropower in Belarus.* The Network of EECCA Water Management Organizations. Available at http://www.eecca-water.net/file/kalinin_alferovich.pdf [in Russian] (Accessed 06 June 2021).
26. Council of Ministers of Belarus (2011). *Resolution of the Council of Ministers of the Republic of Belarus No. 836, on Approving the Regulations on the Procedure for Running the State Cadastre of Renewable Energy Sources and Using its Data, Regulations on the Procedure for Confirming the Origin of Energy Produced from Renewable Energy Sources and Issuing a Certificate Confirming the Origin of Energy and on Amending some Resolutions of the Council of Ministers of the Republic of Belarus of 24 June 2011*. Available at https://www.windpower.by/files/files/en/decree-sm-rb-836-en.docx (Accessed 06 June 2021).
27. President of the Republic of Belarus (2015). *Decree of the President of the Republic of Belarus No. 209 of 18 May 2015, on the Use of Renewable Energy Sources.* Available at https://www.windpower.by/files/files/en/decree-209-en.rtf (Accessed 06 June 2021).
28. President of the Republic of Belarus (2019). *Decree of the President of the Republic of Belarus No. 357 of 24 September 2019, on Renewable Energy Sources.* Available at https://www.windpower.by/files/files/ukaz_357_o_VIE_2019.pdf [in Russian] (Accessed 06 June 2021).
29. Council of Ministers of Belarus (2015). *Resolution of the Council of Ministers of the Republic of Belarus No. 662 of 6 August 2015, on Setting and Allocating Quotas for the Construction of Renewable Energy Facilities.* Available at https://www.windpower.by/files/files/en/decre-662-en.rtf (Accessed 06 June 2021).
30. Ministry of Antimonopoly Regulation and Trade (MART) (2020). *Resolution of the Ministry of Antimonopoly Regulation and Trade of the Republic of Belarus No. 73 of 3 September 2018, on Tariffs for Electricity Produced by Renewable Energy Sources.* Available at https://www.energosbyt.by/images/tariffs/tarif_vozobnovl_ur_l.pdf [in Russian] (Accessed 06 June 2021).
31. Belarusian Telegraph Agency (BelTA) (2015). *New mini-SHP to begin operation in Stolynskiy District before the end of the year.* Available at https://www.belta.by/regions/view/novaja-mini-ges-zarabotaet-v-stolinskom-rajone-do-kontsa-goda-171488-2015/ [in Russian] (Accessed 07 June 2021).
32. Rimkus, E., & Korneev, V. (2014). *Water resource management of the Niemen River basin with account of adaptation to climate change.* Available at https://ehlm.unece.org/download/attachments/30834708/Korneev_Rimkus-Neman_Meeting_Kaliningrad.pdf?version=1&modificationDate=1390809393765&api=v2 [in Russian] (Accessed 07 June 2021).

Bulgaria

Dimitar Kisliakov, University of Architecture, Civil Engineering and Geodesy (UACEG)

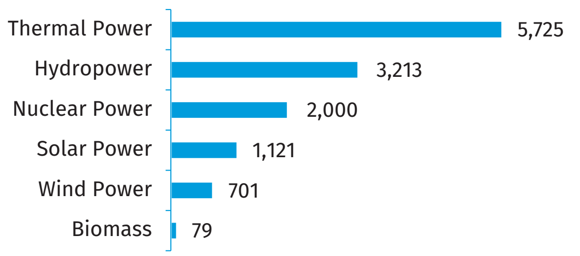
KEY FACTS

Population	6,916,548 (2020)[1]
Area	110,372 km^2 [2]
Topography	The topography of Bulgaria is composed of 31 per cent of lowlands (0–200 metres), 41 per cent of hills (200–600 metres), 25 per cent of highlands (600–1,600 metres) and 3 per cent of mountains (above 1,600 metres).[3] The country exhibits significant topographic variety, with three basic physical divisions running east to west: Northern Bulgaria, defined by the Danubian Plain and the Balkan Mountains; Southern Bulgaria, which includes the Rila Rhodope Massif; and a transitional area in between. The Balkan Mountains reach a height of 2,376 metres at Mount Botev, while the average elevation is 722 metres. The major mountain ranges in Southern Bulgaria include the Rhodope Mountains rising to 2,190 metres, the Pirin Mountains peaking at 2,914 metres and the Rila Mountains, which include the Musala Peak at 2,925 metres, the highest point in the country.[2]
Climate	The five climatic zones of Bulgaria include the moderate continental, intermediate, continental-Mediterranean, maritime and mountainous zones, determined by latitude, topography and distance from the Black Sea, which exerts a moderating influence on the coastal climate. Winters are coldest along the Danube River and mild in the valleys in the southern part of the country along the borders with Greece and Turkey. Summers are hot and dry, owing to the Mediterranean influence. Average monthly temperatures vary from -10.9 °C to 3.2 °C in January and from 5.0 °C to 25.0 °C in July. Temperatures above 35 °C are occasionally recorded in the towns of Rousse and Silistra.[3]
Climate Change	A warming trend has been observed in Bulgaria since the middle of the 1980s. Since 1997, all annual temperature anomalies have been positive, with 2007 experiencing the highest average annual temperature since records began, exceeding the average for the 1961–1990 period by 1.6 °C. Climate change projections for countries on the Balkan Peninsula, including Bulgaria, indicate an increase of 5–8 °C in air temperature during the summer season by 2080, relative to 1961–1990, while the number of summer days is expected to increase by up to 90 days. Air temperatures in the mountains are projected to increase by 2.8–3.2 °C by 2065–2094, relative to the period 2001–2011.[3]
Rain Pattern	The average annual precipitation in Bulgaria is 608 mm, ranging from approximately 450 mm in the north-east to more than 1,190 mm in the mountains. The lowland areas experience snowfall from mid-October to mid-May, with an annual average of 25–30 days of snow cover, while hailstorms occur between May and August.[2,4]
Hydrology	The major rivers internal to Bulgaria include the Maritsa, Iskŭr, Struma, Arda, Tundzha and Yantra, fed by meltwater from the snowfields of the Rhodope, Rila and Pirin Mountain Ranges. The Danube defines the northern border with Romania. Bulgaria has a complex drainage network dominated by relatively short rivers, with more than half the runoff draining into the Black Sea and the rest flowing into the Aegean Sea. In addition, several hundred lakes of glacial origin are present in the country.[2]

ELECTRICITY SECTOR OVERVIEW

In 2020, the total installed capacity in Bulgaria was approximately 12,839 MW. Of this total, thermal power provided 5,725 MW (45 per cent), including 4,365 MW from coal-fired plants and 1,360 MW from gas-fired plants, hydropower provided 3,213 MW (25 per cent), nuclear power 2,000 MW (16 per cent), solar power 1,121 MW (9 per cent), wind power 701 MW (5 per cent) and biomass 79 MW (less than 1 per cent) (Figure 1).[5]

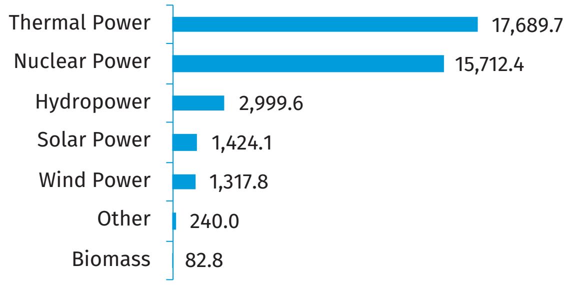
Figure 1. **Installed Electricity Capacity by Source in Bulgaria in 2020 (MW)**



Source: ESO[5]

Gross electricity generation in 2019 amounted to 39,466.3 GWh, with thermal power (coal and natural gas) accounting for 17,689.7 GWh (45 per cent of the total), nuclear power for 15,712.4 GWh (40 per cent), hydropower for 2,999.6 GWh (8 per cent), solar power for 1,424.1 GWh (4 per cent), wind power for 1,317.8 GWh (3 per cent) and biomass and other sources for 322.8 GWh combined (approximately 1 per cent) (Figure 2).[6] Nuclear power still has a decisive role in electricity generation in the country, along with thermal power, despite the recent decommissioning of four 440 MW reactors of the Kozloduy nuclear power plant, with two 1,000 MW reactors remaining in operation. Hydropower, despite its relatively large installed capacity, is employed primarily in a supporting role for providing power during periods of peak demand. The share of run-of-river plants in the total installed capacity is small, with the majority belonging to large reservoir plants on regulated water sources and pumped-storage plants.

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



Source: EWRC[6]

Access to electricity in Bulgaria was 100 per cent as of 2019, as it has been for decades.[7] Electricity consumption in 2019 amounted to 37,628 GWh, exports reached 9,822 GWh, while imports amounted to 4,026 GWh.[6] The reliability of power supply has recently improved due to the changes made in the electricity system management.

The national Electricity System Operator EAD (ESO EAD) is an independent commercial company whose main functions include the operational management of the electricity system of Bulgaria, the implementation of joint work with the electricity systems of other countries, administration of the electricity market and of the balancing energy market, as well as the technical operation and maintenance of the country's electricity transmission network, which is divided into 13 network areas.[8] The total length of the power lines serviced by ESO EAD is over 15,000 kilometres. The ESO EAD supports 288 transformer substations and 5 hub substations. Thirty-two of the substations operated by ESO EAD have a total transformer capacity of over 15,000 MVA. Prior to 2015, ESO EAD was part of the structure of the National Electricity Company EAD (NEK EAD), but that year it was certified as an independent operator of the electricity transmission network. ESO EAD is an active member of the European association for the cooperation of transmission system operators (TSOs) for electricity (ENTSO-E).

The state-owned Natsionalna Elektricheska Kompania EAD (NEK EAD) is the successor to the state-owned energy producer which, prior to 1989, included 22 enterprises in the national energy sector. The company was incorporated in 1991 and currently operates the majority of the hydropower capacity in the country, with other power producers split off from this structure and operating as independent private or state-owned entities. The NEK EAD operates 28 hydropower plants as well as three pumped-storage plants with total installed capacities of 2,737 MW in turbine mode and 931 MW in pumping mode. These plants represent the main regulating capacities in Bulgaria, balancing the operation of nuclear and thermal power plants, the variable loads of solar and wind power plants, as well as industrial and households demand and ensuring control of frequency, capacities exchange and voltage control. Further activities of NEK EAD include electricity trade and the supply of electricity as the public electricity supplier and supplier of last resort.[9]

The national Energy and Water Regulatory Commission (EWRC), established in 1999 and reorganized in 2005 and 2015, is an independent national regulatory body in the fields of electricity, heat energy, natural gas and water. The EWRC is responsible for licensing in the energy sector, setting and regulation of tariffs, monitoring of the quality of services provided by licence holders and dispute resolution. The EWRC is also invested with the power to impose penalties for regulatory breaches.[10]

The annual regulatory period for electricity tariffs starts on 1 July every year. Electricity tariffs for household consumers issued by the EWRC on 1 July 2021 are displayed in Table 1. These tariffs include access and transmission tariffs for customers and exclude the value-added tax (VAT).[11]

Table 1. **Electricity Tariffs for Household Consumers in Bulgaria as of 1 July 2021**

Measuring method	*Time zones*	*Price (BGN/kWh (USD/kWh))*	*Total price including grid services (BGN/kWh (USD/kWh))*
With two scales	Day	0.148 BGN/kWh (0.089 USD/kWh)	0.204 BGN/kWh (0.120 USD/kWh)
	Night	0.058 BGN/kWh (0.035 USD/kWh)	0.115 BGN/kWh (0.069 USD/kWh)
With one scale		0.148 BGN/kWh (0.089 USD/kWh)	0.204 BGN/kWh (0.120 USD/kWh)

Source: Energo-Pro Sales AD[11]

Electricity tariffs for non-household consumers for the period of July–December 2020 are displayed in Table 2.[12] Overall, a slight but constant increase in electricity prices for both household and non-household consumers can be observed in recent years. As in other countries, the impacts of the COVID-19 pandemic have further accelerated this trend.

Table 2. **Electricity Prices for Non-Household Customers in July–December 2020**

Consumption bands	*Annual electricity consumption (MWh)*		*Prices (EUR/kWh (USD/kWh))*				
					Taxes, fees, levies and charges		
	Lowest	*Highest*	*Energy and supply*	*Network costs*	*Total*	*VAT*	*Environmental, including excise duty*
Band 1		< 20	0.0730 (0.086)	0.0284 (0.0330)	0.0215 (0.0250)	0.0205 (0.0240)	0.001 (0.001)
Band 2	20	< 500	0.0675 (0.080)	0.0259 (0.0310)	0.0199 (0.0230)	0.0189 (0.0220)	0.001 (0.001)
Band 3	500	< 2,000	0.0631 (0.074)	0.0188 (0.0220)	0.0176 (0.0210)	0.0166 (0.0200)	0.001 (0.001)
Band 4	2,000	< 20,000	0.0620 (0.073)	0.0155 (0.0180)	0.0167 (0.0200)	0.0157 (0.0180)	0.001 (0.001)
Band 5	20,000	< 70,000	0.0578 (0.068)	0.0140 (0.0170)	0.0156 (0.0180)	0.0146 (0.0170)	0.001 (0.001)
Band 6	70,000	≤ 150,000	0.0578 (0.068)	0.0058 (0.0068)	0.0140 (0.0170)	0.0129 (0.0150)	0.001 (0.001)
Band 7		> 150,000	0.0544 (0.064)	0.0054 (0.0064)	0.0132 (0.0160)	0.0122 (0.0140)	0.001 (0.001)

Source: NSI[12]

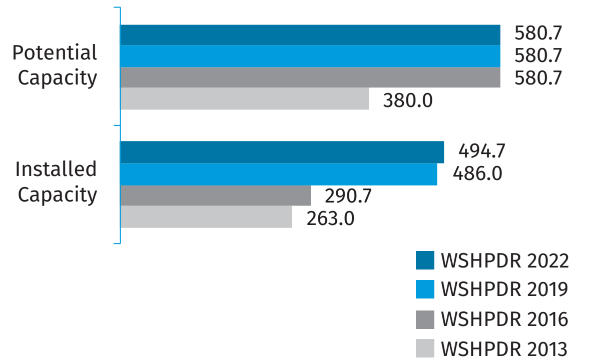
It should be noted that the national electricity market of Bulgaria has been undergoing intensive liberalization, particularly over the last decade. This is a continuous process requiring a significant time commitment and consisting of qualitative changes of the structure and functioning mechanisms of the market. One of the most important aspects of this process was the establishment of a balancing electricity market and its ongoing development. As of 1 October 2020, all non-household consumers connected at low voltage were obliged to purchase their electricity only on the free market.[13] The liberalization process of the electricity market of Bulgaria is governed by numerous national regulations under constant and intensive development, with a legal framework in place to meet the relevant European Union (EU) requirements.[14,15,16] As an example, the latest edition of the Energy Act includes 14 directives of the European Parliament and the Council of the EU and 15 relevant regulations are explicitly mentioned.[14]

SMALL HYDROPOWER SECTOR OVERVIEW

There is no special legislative definition for small hydropower (SHP) in Bulgaria. However, various regulations contain special provisions for SHP plants. These include regulations specifying a 20 kW installed capacity limit for hydropower plants allowed to operate without a water use permit (which must also operate without diversion of the water stream) and regulations setting preferential electricity tariffs for hydropower plants with installed capacities in the 500 kW–10 MW range.[17,18] For the purposes of data comparison, this chapter considers SHP as plants with an installed capacity of up to 10 MW.

As of 2021, there were 245 SHP plants operating in Bulgaria, with a total installed capacity of 494.7 MW.[19,20] Relative to the *World Small Hydropower Development Report (WSHPDR) 2019*, installed capacity increased by approximately 2 per cent, due to more accurate data becoming available. Potential SHP capacity has remained constant, as no new studies of potential capacity have been conducted (Figure 3).[21]

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



Source: ANCHOR,[19] Kisliakov,[20] *WSHPDR 2019*,[21] *WSHPDR 2013*,[22] *WSHPDR 2016*[23]

Note: Data for SHP up to 10 MW.

Between 2016 and 2021, eight SHP projects were completed in Bulgaria, with the majority of these being reconstruction and rehabilitation projects on existing SHP plants, although no official data has been published on these projects.[19,20] A selection of SHP plants commissioned earlier in the decade is displayed in Table 3.

Table 3. **List of Selected Existing Small Hydropower Plants in Bulgaria**

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Type of plant*	*Operator*	*Launch year*
Sabrano	Sabrano	2.17	76.4	Run-of-river	Stroyexpert Engineering –El OOD	2015
Kozloduy	Hurlets (on the outflow canal of the NPP)	5.50	7.2	Run-of-river	VEC Kozloduy EAD	2014
Narechen	Narechen	0.78	20.2	Diversion	Top Agro OOD	2014
Gurkovo	Gurkovo	0.37	36.0	Diversion	Maverik i Ko OOD	2013

Name	Location	Capacity (MW)	Head (m)	Type of plant	Operator	Launch year
Bebresh	Vrachesh	1.04	124.4	Diversion	Agro Engineering EOOD	2012
ERT-1	Gorni Lom	0.22	84.0	Diversion	ERT Hidro EOOD	2012
ERT-3	Gorni Lom	0.15	49.5	Diversion	ERT Hidro EOOD	2012
Sturna	Apriltsi	0.58	114.0	Diversion	Rosina Tsankovi OOD	2012
Cherni Vit	Cherni Vit	0.36	20.4	Diversion	Pro Arm EOOD	2012
Rosa	Mala curkva	1.23	92.3	Diversion	Hidro Eko Vat OOD	2012
Botunya	Stoyanovo	0.50	14.5	Diversion	Hydroenergy Construction EOOD	2011
Brusen	Brusen	0.28	3.6	Diversion	Baldor EOOD	2011
Dushevo	Dushevo	0.28	6.0	Run-of-river	Mira-El OOD	2011
Lakatnik	Lakatnik	2.90	8.8	Run-of-river	VEC Svoge AD	2011
Malusha	Gabrovo	0.40	240.0	Diversion	MVEC Malusha EOOD	2011
Opletnya	Opletnya	2.60	8.0	Run-of-river	VEC Svoge AD	2011
Tserovo	Tserovo	2.50	8.3	Run-of-river	VEC Svoge AD	2011
Lisets	Glozhene	0.23	7.6	Diversion	Energy Plus EOOD	2011
Zarenitsa	Chepelare	0.80	12.3	Diversion	SD Dyulger	2010
Cherepish	Zverino	3.48	7.1	Run-of-river	Ka-5 AD	2010

Source: ANCHOR,[19] Kisliakov[20]

SHP construction in Bulgaria is intensely controversial and currently hindered by a variety of social, political and legislative factors, due to aspects of the recent history of SHP development in the country. Prior to the first edition of the national River Basin Management Plans (RBMP) in 2009, a very large number of water rights permits for hydropower use (primarily for SHP projects) were issued in the country. However, these permits were issued piecemeal, without providing for integrated and environmentally aware development of the affected water bodies and without accounting for the public interest. This in turn generated a significant degree of pushback from non-governmental organizations (NGOs) in the form of social and legal campaigns challenging the ongoing SHP development, which resulted in numerous legal restrictions and prohibitions on SHP enacted by the authorities. At the current stage, these legal changes create a nearly insurmountable obstacle for the implementation of new SHP projects and, while negotiations and revisions to resolve this deadlock are ongoing, these are expected to take significant additional time. Several ongoing SHP projects of indeterminate status as well as several potential SHP sites are listed in Tables 4 and 5, respectively.

Table 4. **List of Selected Ongoing Small Hydropower Projects in Bulgaria**

Name	Location	Capacity (MW)	Head (m)	Type of plant	Developer	Planned launch year
Boaza 2	Gradnitsa	0.02	2.4	Run-of-river	Ekoenergia OOD	2021
Parvomayci	Parvomayci	0.23	2.7	Run-of-river	VEC Parvomayci OOD	2021
Karash	Karash	0.62	5.2	Run-of-river	Bulklima EOOD	2021
Preboynitsa	Gubislav	0.80	140.0	Diversion	Evroenergy MB OOD	2025
Levishte	Gabrovnitsa	3.00	7.8	Run-of-river	VEC Svoge AD	2025

Source: ANCHOR,[19] Kisliakov[20]

Table 5. **List of Selected Potential Small Hydropower Sites in Bulgaria**

Location	Potential capacity (MW)	Head (m)	Type of site (new or refurbishment)
Parvomay	N/A	4.0	Refurbishment
Karadzhalovo	N/A	30.0	Refurbishment
Sevlievo	0.12	86.4	Refurbishment

Source: Kisliakov[20]

RENEWABLE ENERGY POLICY

The key national document outlining renewable energy policy in Bulgaria is the National Renewable Energy Action Plan (NREAP) for the period of 2010–2020, in its 2011 revision, adopted in line with the Directive 2009/28/EC of the European Parliament and the European Council, also known as the Renewable Energy Directive (RED).[24,25] Although somewhat outdated, the NREAP defines preferred renewable energy sources (RES) and outlines the basic vision for meeting renewable energy targets at the time of the Plan's drafting. This includes an overall share target of 16 per cent of gross final energy consumption and 21 per cent of generated electricity to be met by RES by 2020.[25] It should also be noted that in 2019, the annual CO_2-equivalent per capita emissions of Bulgaria, at 5.9 tons, still ranked below the EU average of 6.4 tons.[26]

Following the mandate of EU Regulation 2018/1999 on the Governance of the Energy Union and Climate Action, in 2020 Bulgaria adopted its National Energy and Climate Plan (NECP) for the period of 2021–2030, which heavily emphasized RES development. According to the NECP, Bulgaria plans to increase the share of RES in final energy consumption by a further 9 per cent by 2030, reaching a total of 25 per cent.[27,28]

While Bulgaria has been successful in meeting its targets that were outlined in the 2010 NREAP, subsequent policy changes in Bulgaria caused investors to withdraw and lingering policy uncertainties remain an important factor behind a lack of confidence in RES amongst investors and banks.[27] The changes that triggered this reversal included the abandonment of economically unsustainable subsidies for RES and long-term power purchase agreements (PPAs) as well as the correction of market deformations induced by excessive investor confidence.[22] Additional obstacles are posed by the complexity of administrative procedures, the expense and the length of time required to obtain the necessary licences and permits to construct and operate RES facilities, caused in part by a lack of coordination by government agencies and national and local authorities on the issue of RES licensing.[26]

Policy on incentives for RES in Bulgaria is informed by the Guidelines on State Aid for Environmental Protection and Energy for 2014–2020, released by the European Commission in 2014. The document required EU Member States to implement a pilot bidding process for part of their RES projects in 2015–2016 and, starting with 2017, to implement competitive bidding as the only means of support for all new RES capacities, with feed-in premiums (FIP) and green certificates being the primary mechanisms for the bidding process and feed-in tariffs (FITs) retained only in the case of small-scale RES installations below 1 MW.[29]

In the case of Bulgaria, the FIT support scheme was terminated in 2009 for power plants using RES with a total installed capacity of over 4 MW, replaced by the FIP scheme.[24] Subsequently, in July 2021, the FIT scheme was also terminated for most RES plants with an installed capacity of up to 4 MW, with only plants with an installed capacity of up to 1 MW still supported by FIT and the rest required to sell their energy on the free market, bringing the FIT policy of Bulgaria in line with EU legislation. FITs in Bulgaria are issued for a guaranteed purchase period set by the PPA, which varies based on the type of RES: 20 years for solar power, geothermal power and biomass; 15 years for biogas and SHP; and 12 years for wind power.[30] The most significant additions of wind and solar power capacity in the country took place in 2011–2012, with some 1.5 GW added. This occurred when a FIT scheme with a high support level was in place at the same time as technology costs were falling, worldwide. Currently, the opposite trend is being observed, in large part due to the effects of the COVID-19 pandemic.

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

With the national and EU level policy setting the boundary conditions for RES development in Bulgaria, SHP projects specifically are subject to the following additional regulations:

- The Water Act (most recently amended on 26 February 2021), which regulates the property and management of water resources on the territory of the Republic of Bulgaria and the related facilities. The Water Act includes several significant restrictions on hydropower development in the country, including a prohibition on the construction of SHP cascades, without including an explicit legislative definition of cascade, and a prohibition on hydropower construction on rivers in protected areas, streams with an average discharge of less than 100 l/s, or any hydropower construction that disturbs the hydraulic continuity of a watercourse;
- The Environmental Protection Act (last amended on 12 March 2021), which regulates the basic issues related to environmental protection in Bulgaria;
- Ordinance on the use of surface water, formulating the terms and conditions for the use of surface water bodies on the territory of Bulgaria;
- The Act on Protected Territories (last amended on 12 March 2021), which regulates the basic issues related to the rank, status, activities and protection of protected territories in Bulgaria;
- The Spatial Development Act (last amended on 12 March 2021), which regulates the basic issues of a building process and all related problems of the territory development and connection;
- The Law on Energy from Renewable Sources (last amendment of 12 March 2021), which regulates the specific issues related to the RES, their development and use.[18,31,32,33,34,35]

COST OF SMALL HYDROPOWER DEVELOPMENT

The cost of construction of SHP plants in Bulgaria per MW, including all preliminary studies, administrative and design activities, varies across a broad range—from approximately EUR 1 million to more than EUR 3.5 million. Factors affecting cost include both the implemented technical solutions and the time of construction. Consequently, the payback period for SHP projects can likewise vary anywhere from 3 to over 15 years. Overall, the cost has changed significantly in the last 20 years. A particular issue in Bulgaria is the incidence of rushed SHP projects caused by investor pressure. These have contributed to environmental problems and the negative reputation of SHP in the country.

EFFECTS OF CLIMATE CHANGE ON SMALL HYDROPOWER DEVELOPMENT

Climate change in Bulgaria is expected to significantly impact the amount and temporal distribution of precipitation in the coming decades. Annual precipitation is projected to decrease by approximately 15 per cent by 2050 and by 30–40 per cent by 2080, relative to the 1961–1990 baseline period. Seasonally, precipitation distribution is projected to become more uneven, with excess precipitation in the winter to be offset by drought during the summer months. These changes are expected to negatively impact the generation capacity and reliability of generation by hydropower in the country. Additionally, drought risk will increase competition for water use from various sectors, including thermal power plants that abstract and discharge water for cooling purposes.[36]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The main barriers to SHP development currently present in Bulgaria could be summarized as follows:

- Hydrological information is not publicly accessible, with the occasional exception of primary data that needs further qualified processing;
- Successive closure of nearly all local turbine and generator producing capacities in Bulgaria after 1989 (at the time, Bulgaria produced, under licence, large reversible pump-turbines with the highest head in the world), as well as the disbandment of all research and development units for hydraulic machinery;
- Significant legislative barriers to hydropower development included in the Water Act;
- Construction of hydropower plants is also prohibited at sites included in the River Basin Management Plans (RBMPs);
- More generally, SHP development in Bulgaria is not economically feasible without extensive support in the form of FIT and FIP mechanisms.

The key enablers for SHP development in Bulgaria include the following:

- Open electricity and financial markets;
- FITs for SHP are considerably higher than for large hydropower;
- Extensive financing options for SHP, including opportunities for credit from banks subject to negotiations on a case-by-case basis, direct private investments and different forms of public-private partnerships. In the frame of special temporarily available trust funds and programmes supported by the EU, financing of SHP projects also is possible under favourable conditions.

It should be noted, however, that the temporary political, economic and social uncertainty related to the COVID-19 pandemic has recently caused investors to refrain from complicated long-term projects with relatively low revenue rates. It should be additionally emphasized that an increasingly broad consensus is developing in Bulgaria on the need to ensure that investment projects, and SHP projects in particular, are sustainable, in the sense that the balance between social, environmental and economic needs is assigned the highest priority.

REFERENCES

1. National Statistical Institute (NSI) (n.d.). *Population (Demography, Migration and Projections)*. Available at https://www.nsi.bg/en/content/6704/population-districts-municipalities-place-residence-and-sex (Accessed 26 July 2021).
2. Encyclopaedia Britannica (n.d.). *Bulgaria*. Available at https://www.britannica.com/facts/Bulgaria (Accessed 26 July 2021).
3. Climate change Post (n.d). *Climate Change Bulgaria*. Available at https://www.climatechangepost.com/bulgaria/climate-change/ (Accessed 26 July 2021).
4. World Bank (n.d.) *Average annual precipitation (mm per year) - Bulgaria*. Available at https://data.worldbank.org/indicator/AG.LND.PRCP.MM?locations=BG (Accessed 26 July 2021).
5. Electricity System Operator (ESO) (2020). *Statistical Booklet 2020*. Available at https://www.eso.bg/fileObj.php?oid=3178 [in Bulgarian] (Accessed 25 May 2022).
6. Energy and Water Regulatory Commission (EWRC) (2020). *Annual Report to the European Commission, 2020*. Available at https://www.dker.bg/uploads/2019/EWRC_Report_to_EC_2019_EN.pdf (Accessed 12 September 2021).
7. World Bank (n.d.). *Access to electricity (% of the population) – Bulgaria*. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=BG (Accessed 30 July 2021).
8. Electricity System Operator EAD (ESO) EAD (n.d.). *About Us*. Available at http://www.eso.bg/index.php?en (Accessed 12 September 2021).
9. Natsionalna Elektricheska Kompania (NEK) EAD (n.d.). *About us*. Available at https://nek.bg/index.php/en/about-us-new (Accessed 12 September 2021).
10. Energy and Water Regulatory Commission (EWRC) (n.d.). *General information*. Available at https://www.dker.bg/bg/za-kevr/obscha-informatsiya.html [in Bulgarian] (Accessed 12 September 2021).
11. Energo-Pro Sales AD (2021). *Current electricity tariffs for domestic consumers as of 01.07.2021*. Available at https://energo-pro-sales.bg/bg/za-klienta/klienti-na-reguliran-pazar/ceni-na-elektroenergijata/dejstvashti-ceni-na-elektroenergijata-za-bitovi-klienti-ot-01-07-2021-g [in Bulgarian] (Accessed 12 September 2021).
12. National Statistical Institute (NSI) (2020). *Electricity prices for final non-household customers*. Available at https://www.nsi.bg/en/content/5035/electricity-prices-final-non-household-customers (Accessed 31 July 2021).
13. Energy and Water Regulatory Commission (EWRC) (2020). *Decision № C-29 / 01.07.2020 of the Energy and Water Regulatory Commission*. Available at https://www.dker.bg/bg/resheniya/resheniya-za-2020-god.html [in Bulgarian] (Accessed 12 September 2021).
14. Bulgarian Law Portal (2021). *Energy Act*. Available at https://lex.bg/laws/ldoc/2135475623 [in Bulgarian] (Accessed 12 September 2021).
15. State Gazette (2014). *Electricity trading rules, latest changes and amendments*. Published in the State Gazette, Issue 40 from 9 May 2014. Available at https://dv.parliament.bg/DVWeb/broeveList.faces# [in Bulgarian] (Accessed 12 September 2021).

16. State Gazette (2020). *Methodology for determining balancing energy prices.* Published in the State Gazette, Issue 39 from 5 May 2020. Available at https://dv.parliament.bg/DVWeb/broeveList.faces# [in Bulgarian] (Accessed 12 September 2021).
17. Energy and Water Regulatory Commission (EWRC) (2021). *Decision No. C-25 / 01.07.2021 of the Energy and Water Regulatory Commission.* Available at https://www.dker.bg/bg/resheniya/resheniya-za-2021-god.html [in Bulgarian] (Accessed 12 September 2021).
18. Bulgarian Law Portal (2021). *Water Act.* Available at https://www.lex.bg/laws/ldoc/2134673412 [in Bulgarian] (Accessed 16 September 2021).
19. Vasilev, V., Uzunova, E., Kisliakov, D., Tsonev, R., Thaulow, H., Nesheim, I., Todorov, D. & Rangelov, K. (2017). *Assessment of the Combined Hydropower Impacts on the Ecosystems and Ecological Status of Rivers (ANCHOR) – final report*. The Regional Environmental Center for Central and Eastern Europe - Bulgaria. ISBN 978-954-9867-10-7.
20. Kisliakov, D. (2021). Internal data and personal communication with ANCHOR project partners (unpublished).
21. 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.
22. 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.
23. 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.
24. European Parliament and the Council of the European Union (2009). *Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009*. Available at https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32009L0028 (Accessed 20 September 2021).
25. Ministry of Economy, Energy and Tourism (2010). *National Renewable Energy Action Plan (2020)*. Available at https://ec.europa.eu/energy/sites/ener/files/documents/dir_2009_0028_action_plan_bulgaria.zip (Accessed 20 September 2021).
26. International Renewable Energy Agency (IRENA) (2019). *Renewable Energy Market Analysis: Southeast Europe*. IRENA, Abu Dhabi. ISBN 978-92-9260-166-9. Available at https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Dec/IRENA_Market_Analysis_SEE_2019.pdf (Accessed 20 September 2021).
27. European Parliament and the Council of the European Union (2018). *Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action*. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?toc=OJ:L:2018:328:TOC&uri=uriserv:OJ.L_.2018.328.01.0001.01.ENG (Accessed 20 September 2021).
28. Ministry of Energy (MoEN) & Ministry of Environment and Water (MoEW) (2020). *Integrated Energy and Climate Plan of the Republic of Bulgaria 2021-2030*. Available at https://ec.europa.eu/energy/sites/ener/files/documents/bg_final_necp_main_en.pdf (Accessed 20 September 2021).
29. European Commission (2014). *Guidelines on State aid for environmental protection and energy 2014-2020*. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52014XC0628%2801%29 (Accessed 31 July 2021).
30. Danailova, Todorov and Partners (n.d.). *Renewable Energy Sources (RES) Policy and Laws in Bulgaria.* Available at https://lawfirm.bg/en/publications/feed-in-tariff (Accessed 21 September 2021).
31. Bulgarian Law Portal (2021). *Environment Protection Act.* Available at https://www.lex.bg/laws/ldoc/2135458102 [in Bulgarian] (Accessed 21 September 2021).
32. Bulgarian Law Portal (2021). *Decree No. 100 from 23 March 2021 on the adoption of the Ordinance on the use of surface water*. Available at https://lex.bg/bg/laws/ldoc/2137211129 [in Bulgarian] (Accessed 21 September 2021).
33. Bulgarian Law Portal (2021). *Act on Protected Territories*. Available at https://www.lex.bg/laws/ldoc/2134445060 [in Bulgarian] (Accessed 21 September 2021).
34. Bulgarian Law Portal (2021). *Spatial Development Act*. Available at https://www.lex.bg/laws/ldoc/2135163904 [in Bulgarian] (Accessed 21 September 2021).
35. Bulgarian Law Portal (2021). *Law on Energy from Renewable Sources*. Available at https://www.lex.bg/laws/ldoc/2135728864 [in Bulgarian] (Accessed 21 September 2021).
36. Republic of Bulgaria (2018). *Proposal for a National Climate Change Adaptation Strategy and Action Plan. (Draft from 4 May 2018).* Available at https://www.moew.government.bg/static/media/ups/tiny/%D0%9F%D0%98%D0%9A/%D0%9C%D0%9F%D0%90/Strategy%20and%20Action%20Plan%20-%20Full%20Report%20-%20Draft%20(2018-05-03)%20-%20EN%20V4.EM.pdf (Accessed 21 September 2021).

Czech Republic

Pavel Štípský, chairman, and Helena Kamrlová, SPVEZ, z. s.

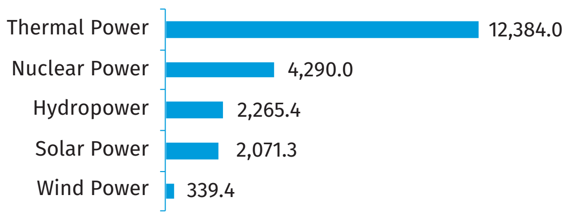
KEY FACTS

Population	10,698,896 (2020)[1]
Area	78,867 km^2[2]
Topography	There are two main regions in the Czech Republic: Bohemia in the west and Moravia in the east. Bohemia occupies the major portion of the territory and consists of the Bohemian Plateau surrounded by six mountain groups. Moravia occupies most of the eastern part of the country and is characterized by a hilly relief in the eastern part and a lowland character in the central part of the region. Mount Sněžka, at 1,603 metres, is the highest point of the country and lies in the east in the Krkonoše Mountains.[3]
Climate	The climate of the Czech Republic is mild but varies throughout the year and across regions, depending on the altitude. Temperatures are rather uniform in the low-lying areas of the country but decrease at higher elevations. January is the coldest month, with average temperatures in the lowlands reaching below 0 °C. Summer temperatures average at 20 °C but can exceed 30 °C in some parts of the country in July. Snow coverage usually lasts for several months at higher altitudes and only for several days in the lowlands.[4]
Climate Change	Climate change projections in the Czech Republic predict an increase in average seasonal temperatures of approximately 1.1–1.2 °C by 2030, while increases in average monthly temperatures are expected to reach approximately 3–4 °C in July and August by 2069, relative to the 1960–1990 reference period.[5]
Rain Pattern	Most precipitation falls in the months of June and July, while the months of January and February exhibit the least precipitation. In winter, precipitation occurs mainly in the mountains in the form of snow. Annual precipitation can vary significantly, from 410 mm to 1,700 mm. However, in most years precipitation is between 600 mm and 800 mm.[4]
Hydrology	The territory of the Czech Republic includes the main water divide of Europe, separating the North Sea, Baltic Sea and the Black Sea drainage basins. One of the major rivers of the country is the Elbe, with its tributaries the Vltava and Ohře, which drains most of the territory of Bohemia and flows into the North Sea. The Morava River, together with its tributaries, drains a major part of Moravia and flows into the Danube River. The Odra River, flowing into the Baltic Sea, drains a part of northern Moravia including the region of Slezia. The highest discharge is observed in the spring months as a result of snow melting in the mountains.[3,4,6]

ELECTRICITY SECTOR OVERVIEW

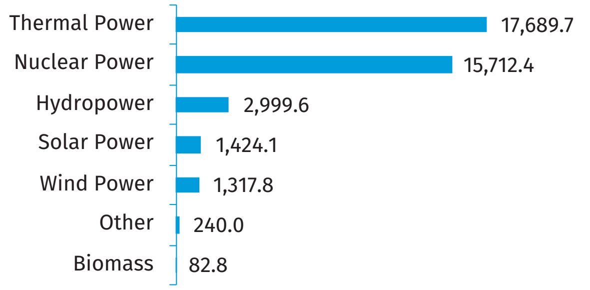
The total installed capacity of the Czech Republic amounted to 21,350.1 MW at the end of 2020, of which thermal power accounted for 12,384.0 MW (58 per cent), nuclear power for 4,290.0 MW (20 per cent), hydropower for 2,265.4 MW (11 per cent), solar power for 2,071.3 MW (10 per cent) and wind power for 339.4 MW (2 per cent) (Figure 1).[7] Electricity generation in 2020 reached 81,443.6 GWh, decreasing from 86,990.5 GWh in 2019. Conventional thermal power including gas-fired and coal-fired power plants provided 39,609.8 GWh (49 per cent) of the annual generation total, nuclear power provided 30,043.3 GWh (37 per cent), biomass and biogas provided 5,093.6 GWh (6 per cent), hydropower provided 3,437.0 GWh (4 per cent), solar power provided 2,235.1 GWh (3 per cent), wind power provided 699.1 GWh (1 per cent) and other sources provided 325.7 GWh (less than 1 per cent) (Figure 2).[7,8]

Figure 1. **Installed Electricity Capacity by Source in the Czech Republic in 2020 (MW)**



Source: ERO[7]

Figure 2. **Annual Electricity Generation by Source in the Czech Republic in 2020 (GWh)**



Source: ERO,[7] MIT[8]

Access to electricity in the Czech Republic is 100 per cent.[9] Total gross domestic consumption of electricity in 2020 amounted to 71,354 GWh, which included system losses of 4,117 GWh (approximately 5 per cent of gross annual generation). Imports in 2020 amounted to 13,368 GWh, while exports reached 23,520.9 GWh.[7]

The energy sector of the Czech Republic is regulated by the Energy Regulatory Office (ERO). Its responsibilities include price control, promotion of renewable and secondary energy sources, support for heat and power generation, granting of licensing permissions, protection of consumers and fair competition and supervision of the energy market. ERO additionally issues price decisions and compiles statistical data.[10]

The main participants of the electricity market of the Czech Republic include the Czech Transmission System Operator (ČEPS), distribution sector operators (DSOs), electricity generators, the market operator, electricity traders and consumers. ČEPS is a state-owned enterprise and is controlled by the Ministry of Industry and Trade (MIT), which holds an exclusive licence to maintain and operate the transmission system. The distribution network is privately operated, with major distributors including ČEZ Group, E.ON Energy and Prague Energy (PRE).

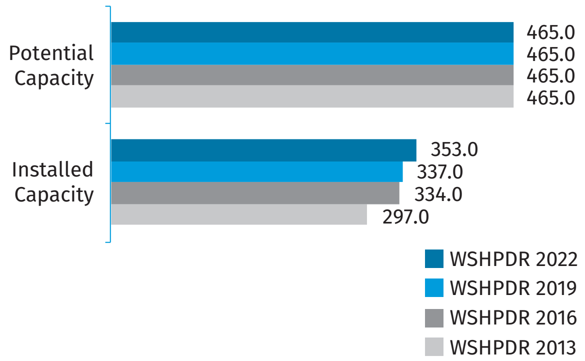
The price of the power component of electricity is determined on the market by individual suppliers, while the price for electricity transmission and other support services for final consumers as well as contributions to subsidies for renewable energy sources (RES) are regulated by ERO in its regular price decisions. The final tariffs for electricity depend on the category of consumer, level of consumption, chosen supplier and the length of the contract. The average price for household consumers ranged between 0.15 EUR/kWh and 0.25 EUR/kWh (0.17–0.28 USD/kWh) in 2019.[11] Substantial electricity price increases are expected for end users whose long-term fixed-price contracts are due to expire in 2022 due to the ongoing global energy crisis.[12]

SMALL HYDROPOWER SECTOR OVERVIEW

Small hydropower (SHP) plants are defined in the Czech Republic as hydropower plants with an installed capacity of up to 10 MW. SHP plants fall in the category of supported sources of electricity, which receive state subsidies to ensure their economic viability under the current market conditions.

As of 2020, there were 1,422 SHP plants in the Czech Republic with a total installed capacity of 353 MW and an annual production of 1,227 GWh.[12] Potential capacity for SHP in the country has been estimated at 465 MW in 2007, indicating that approximately 76 per cent has been developed so far.[13] Relative to the *World Small Hydropower Development Report (WSHPDR) 2019*, installed SHP capacity has increased by approximately 5 per cent due to the commissioning of new plants. Potential capacity has remained static as no new comprehensive studies of SHP potential in the country have been carried out (Figure 3).[14]

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



Source: Štípský & Kamrlová,[12] Punys & Pelikan,[13] *WSH PDR 2019*,[14] *WSHPDR 2013*,[15] *WSHPDR 2016*[16]

The majority of operating SHP plants in the Czech Republic (953 plants) are micro-scale with a capacity of up to 100 kW and a total capacity of 38 MW. Micro-hydropower plants are typically located on historic sites such as old water mills, sawmills, glassworks and textile factories and are distributed fairly evenly across the territory of the country. Larger plants are located on major rivers, with SHP plants on the Elbe River accounting for a quarter of all installed SHP capacity.[12]

Owing to their territorial distribution, SHP plants play the role of decentralized sources of electricity generation. They do not burden the transmission system and thus have minimal transmission losses. Additionally, SHP plants improve the technical parameters at the endpoints of the low-voltage network, which helps to stabilize the network. In the Czech Republic, SHP plants are owned and operated by a variety of entities numbering approximately 1,100 independent operators, including individuals, various commercial and non-commercial entities and state water companies.

Approximately a third of SHP plants in the country are operated by the state through the majority state-owned ČEZ Group and the state-owned group of companies Povodí.[12]

Although previous studies have estimated total potential capacity of SHP in the Czech Republic in the hundreds of megawatts, technically and economically feasible potential in the country is almost entirely exhausted. According to a qualified estimate by the Czech Union of Entrepreneurs for the Use of Energy Resources (SPVEZ), the remaining realistically exploitable potential ranges from 35 MW to 50 MW, mainly composed of potential micro-hydropower sites with low individual capacities. More extensive development is not possible due to the long periods required to achieve financial returns on investment. Additionally, the remaining technically feasible SHP sites are situated mainly in mountainous areas, national parks and protected zones, where legislation either does not permit SHP development at all or renders it prohibitively complicated and costly. Additionally, the National Renewable Energy Action Plan (NREAP) adopted in 2012 set a total installed capacity target of 153 MW for SHP under 1 MW and 191 MW for SHP of 1–10 MW by 2020. This target had been exceeded as of 2018.[12,17]

The scale of recent SHP construction has consequently been quite small. In 2020, only 11 new SHP plants were commissioned in the country, with a total installed capacity of approximately 1 MW. A list of these plants is provided in Table 1. No information on ongoing or planned SHP projects in the country is available as private investors in the Czech Republic do not typically publicly advertise such plans.[12]

Table 1. **List of Small Hydropower Plants Commissioned in the Czech Republic in 2020**

Name	*Capacity (MW)*	*Launch year*
Ejpovice	0.314	2020
Papouščí skála	0.240	2020
Bohdíkov	0.150	2020
Perla Chocen II	0.132	2020
Trávníček	0.055	2020
Nišovice	0.037	2020
Rožmitál pod Třemšínem	0.030	2020
Nádražní	0.025	2020
Břevnice	0.019	2020
Bílkovice	0.019	2020
Střížeš nad Bečvou	0.018	2020
Total	**1.039**	

Source: Štípský & Kamrlová[12]

RENEWABLE ENERGY POLICY

In the Czech Republic, renewable energy projects are supported through either a guaranteed feed-in tariff (FIT) or a green bonus paid on top of the market price. The support schemes for electricity generation from renewable energy sources were first outlined in the 2012 Act on Supported Energy Sources (Act No. 165/2012). However, in 2013, the Act was amended by Act No. 310/2013, which abolished FIT support for all renewable energy projects put into operation after 31 December 2013, with the exception of SHP plants up to 10 MW. SHP plants commissioned on or prior to 31 December 2021 are eligible to choose between the FIT and the green bonus. Following additional amendments to the Act on Supported Energy sources adopted in October 2021, SHP plants commissioned on or after 1 January 2022 are not eligible for FIT support, and can receive support either in the form of green bonuses or auction bonuses.[18]

In October 2021, the years-long process of amending the Act on Supported Energy Sources and the Energy Act was completed. Among other functions, these two laws regulate the legislative framework for SHP for the next decade. Major changes included the introduction of an auction system of operating aid for newly commissioned RES plants, the setting of an internal rate of return (IRR), profitability checks of existing RES plants to avoid possible overcompensation and other measures. Future expected amendments include the shortening of the operating support period from 30 years to 20 years and stricter connection conditions. According to the amended Act on Supported Energy Sources, new SHP plants with a capacity of up to 1 MW are offered support in the form of a green bonus, while those with a capacity of 1-10 MW are offered support in the form of an auction bonus. However, in the context of the energy crisis and unpredictability in the entire energy sector across Europe during 2022, the Czech government has not, as of the first half of 2022, announced any RES auctions. There is also a continuing effort to enact an increase of the minimum permissible residual flows for watercourses, which would mean a further significant deterioration of the economic feasibility of SHP operation in the country.[12]

The FITs for still-eligible SHP plants are established by ERO on an annual basis. If a producer opts for the FIT, the contracted electricity distributor will be obliged to purchase all produced electricity. According to the 2005 Act on the Promotion of Electricity Production from Renewable Energy Sources, this scheme ensured investment payback within 15 years. The amended Act on Supported Energy Sources no longer provides for a guarantee of payback for newly commissioned plants, but only defines the conditions for determining the amount of operating aid that would ensure the sum of discounted cash flows over the lifetime of the plant is equal to zero. Green bonuses are calculated based on the time elapsed after the commissioning of the plant and represent a bonus to the market price of electricity, to which the producer is entitled for the electricity sold to a final customer or electricity trader. The plant operator receives this bonus from the state-owned Operator of the Electricity Market (OTE). In addition to these two schemes, RES projects can also receive investment subsidies.[16] Purchase prices and green bonuses for SHP plants established by Price Decision No. 6/2021 from 29 September 2021 are displayed in Table 2.

Table 2. **Purchase Prices and Green Bonuses for Small Hydropower in the Czech Republic in 2019–2021**

Type of SHP plant	*Year of commissioning*	*Purchase price (CZK/MWh (USD/MWh))*	*Green bonus (CZK/MWh (USD/MWh))*
SHP plants on established sites*	2019	2,349 (108.1)	1,154 (53.1)
	2020	2,303 (105.9)	1,108 (51.0)
	2021	2,258 (103.9)	1,063 (48.9)
Renovated SHP plants	2019	2,349 (108.1)	1,154 (53.1)
	2020	2,303 (105.9)	1,108 (51.0)
	2021	2,258 (103.9)	1,063 (48.9)
SHP plants in new locations	2019	2,909 (133.8)	1,714 (78.8)
	2020	2,852 (131.2)	1,657 (76.2)
	2021	2,796 (128.6)	1,601 (73.6)

Source: ERO[19]

Note: *referring to sites with an active power plant and grid connection as of 1995 or later.

From the first half of 2021, however, a significant rise in the prices of the power components of electricity has been observed across the European Union, which has had a major impact on the electricity sector in the Czech Republic and the SHP sector in particular. In response to an increase in market prices for electricity, purchase price subsidies for RES are decreasing. In particular, ERO has set the operating support for SHP plants in the form of green bonus at 0 CZK/kWh in its price decision for 2023, due to the significant increase in the market price of electricity and the consequent expectation that SHP plants will have become fully competitive by that date and no longer require support. As of June 2022, it was not possible to make a qualified prediction on future price dynamics, although in July, traders started publishing price lists for new contracts with substantial increases in the price of the power component of electricity.[12]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

Key regulations for SHP plants are established by the Water Law of the Czech Republic. Permits for the construction of any hydraulic structure including SHP plants are issued by the relevant Water Legal Office and require the submission of the following documents:

- Documents in line with the Building and Spatial Planning Law regulations, including the opinion of the local administration department;
- Design documentation, including a water legal action plan and a description of the potential hydraulic and ecological impact, impact on protected areas and information on the main discharge indicators;
- Opinion of the relevant water basin administrator and the administrator of the specific watercourse;
- Water use concessions and/or building permits previously issued by other offices;
- Maps and any other relevant documents pertaining to the planned inundation area in case of plants with a reservoir.

SHP investors are expected to apply for a grid connection with the relevant distribution system operator simultaneously with applying for a construction permit. Along with other RES, SHP plants receive priority for grid connections over conventional plants. Finally, SHP plant operators must apply for an operating licence with the ERO.[20]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Climate change modelling predicts an overall minor decrease in streamflow and a significant increase in streamflow uncertainty over the course of the 21st century. Relative to the 1981–2010 control period, a 12 per cent reduction in mean flow is predicted for the 2061–2080 time horizon and a 17 per cent reduction for the 2080–2100 time horizon. Uncertainty of streamflow predictions oscillated by a factor of four over 34 climate models for the time horizon of 2021–2040, indicating that outflow from rivers could be either half or twice of its volume during the control period, with uncertainty increasing substantial for further time horizons. While this uncertainty does not reflect likely streamflow scenarios, it significantly complicates long-term planning of the development of hydrological resources in the country.[21]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

While SHP has a significant presence in the Czech Republic, further development of SHP in the country is limited by several factors:

- High operation and maintenance costs;
- Complicated licensing process;
- Prioritization of fossil fuels and nuclear power over RES in the country's energy strategy;
- Gradual reduction in financial support for RES development as a whole;
- Existing regulations limiting SHP development at many potential sites;
- Political and social pushback to SHP development, with possible future restrictions on streamflow reduction to further undermine economic prospects for SHP;
- Largely exhausted undeveloped SHP potential and a lack of remaining prospective sites for development;
- Expected adverse impacts of climate change on river flow.

Enabling factors for SHP development in the Czech Republic include:

- Historical experience and domestic technical capacity for the operation and development of SHP plants and equipment;
- Several existing support schemes including FITs, green bonuses and investment subsidies;
- Some remaining undeveloped potential capacity;
- Potential for the refurbishment of existing SHP plants, specifically provided for in the RES support structure.

REFERENCES

1. World Bank (n.d.). *Population, total – Czech Republic*. Available at https://data.worldbank.org/indicator/SP.POP.TOTL?locations=CZ (Accessed 23 January 2022).
2. Nations Online (n.d.). *Czech Republic*. Available at https://www.nationsonline.org/oneworld/czech_republic.htm (Accessed 23 January 2022).
3. Nations Encyclopedia (n.d.). *Czech Republic*. Available at http://www.nationsencyclopedia.com/Europe/Czech-Republic.html (Accessed 23 January 2022).
4. Czech Hydrometeorological Institute (n.d.). *Official website*. Available at https://www.chmi.cz/?l=en (Accessed 23 January 2022).
5. Ministry of the Environment (2017). *Seventh National Communication of the Czech Republic under the United Nations Framework Convention on Climate Change including Supplementary Information pursuant to Article 7.2 of the Kyoto Protocol*. Available at https://unfccc.int/sites/default/files/resource/17589243_Czech%20Republic-NC7-BR3-1-NC7_BR3_CZE.pdf (Accessed 23 January 2022).
6. United Nations Global Compact CEO Water Mandate (n.d.) *Interactive Database of the World's River Basins*. Available at http://riverbasins.wateractionhub.org/ (Accessed 23 January 2022).
7. Energy Regulatory Office (ERO) (2020). *Annual report on the operations of the electricity system of the Czech Republic for 2020*. Available at https://www.eru.cz/documents/10540/6616306/Rocni_zprava_provoz_ES_2020.pdf/edc0cb03-700a-43a7-8c08-a1ccb3f2d173?_x_tr_sl=cs&_x_tr_tl=en&_x_tr_hl=en-US&_x_tr_pto=wapp [in Czech] (Accessed 24 January 2022).
8. Ministry of Industry and Trade (MIT) (2020). *Renewable energy sources in 2020*. Available at https://www.mpo.cz/assets/cz/energetika/statistika/obnovitelne-zdroje-energie/2021/9/Obnovitelne-zdroje-energie-2020.pdf?_x_tr_sl=cs&_x_tr_tl=en&_x_tr_hl=en-US&_x_tr_pto=wapp [in Czech] (Accessed 24 January 2022).
9. World Bank (n.d.). *Access to electricity (% of population) – Czech Republic*. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=CZ (Accessed 24 January 2022).
10. Energy Regulatory Office (ERO) (n.d.). *About ERO*. Available at https://www.eru.cz/en/o-uradu (Accessed 24 January 2022).
11. Energy Regulatory Office (ERO) (n.d.). *Price decisions*. Available at https://www.eru.cz/cs/poze/cenova-rozhodnuti [in Czech] (Accessed 24 January 2022).
12. Štípský, P. & Kamrlová, H. (2022). Authors' personal expertise and data received from ERO, SPVEZ z.s. and other stakeholders.
13. Punys, P. & Pelikan, B. (2007). Review of small hydropower in the new Member States and Candidate Countries in the context of the enlarged European Union. *Renewable and Sustainable Energy Reviews, 11* (7), pp. 1321-1360.
14. 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.
15. 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.
16. 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.
17. Ministry of Industry and Trade (MIT) (2012). *National Renewable Energy Action Plan of the Czech Republic*. Available at https://www.mpo.cz/assets/dokumenty/48181/54290/599682/priloha001.pdf [in Czech] (Accessed 24 January 2022).
18. United Nations Development Programme (UNDP) (n.d.). *Renewable Energy Snapshot: Czech Republic*. Available at http://www.eurasia.undp.org/content/dam/rbec/docs/Czech%20Republic.pdf (Accessed 24 January 2022).
19. Energy Regulatory Office (ERO) (2021). *Price Decision No.6/2021*. Available at https://www.eru.cz/documents/10540/7274234/ERV08_2021.pdf/321b0dcb-3183-46c6-b75c-1ac16c536c26?_x_tr_sl=cs&_x_tr_tl=en&_x_tr_hl=en-US&_x_tr_pto=wapp [in Czech] (Accessed 24 January 2022).
20. European Small Hydropower Association (ESHA) (2012). *Small hydropower roadmap: condensed research data for EU-27*. Available at https://www.globalccsinstitute.com/archive/hub/publications/138208/small-hydropower-roadmap-condensed-research-data-EU-27.pdf (Accessed 24 January 2022).
21. Sýs, V., Fošumpaur, P. & Kašpar, T. (2021). The Impact of Climate Change on the Reliability of Water Resources. *Climate*, *9*(11), 153. Available at https://www.mdpi.com/2225-1154/9/11/153/htm (Accessed 24 January 2022).

Hungary

Béla Munkácsy and José Campos, Eötvös Loránd University

KEY FACTS

Population	9,772,756 (2019)[1]
Area	93,030 km^2 [2]
Topography	Flat terrain prevails as the county is dominated by the Great Hungarian Plain east of the Danube. Most of the country lies at an elevation of less than 200 metres above sea level. The highest point is Mount Kekes (1,014 metres) in the Matra Mountains, north-east of Budapest. The lowest point lies at 75.8 metres above sea level, at the Tisza River, near Szeged.[2]
Climate	Hungary is characterized by a temperate climate, with cold, cloudy and humid winters and warm summers. The average annual temperature ranges between 10 °C and 11 °C. July and August are the warmest months with an average temperature of 21 °C, whereas December and January are the coldest months with an average temperature of 0 °C.[3]
Climate Change	Climate change is expected to cause significant warming in Hungary with seasonal warming of 1-3 °C for the 2021-2050 period. While total annual precipitation is projected not to change significantly, seasonal variations are expected. Summer precipitation is likely to decrease, while autumn and winter precipitation is likely to increase during the 21st century.[4]
Rain Pattern	Total mean annual precipitation is approximately 600 mm. June is the wettest month, with an average precipitation of 70 mm, and February is the driest, with 30 mm of rainfall.[5]
Hydrology	Hungary has moderate water resources, which is explained by the plain-dominated topography. The two most important rivers are the Danube (length: 417 km; average flow: approximately 2,000 m^3/s; fall in the Hungarian section: 30 m; average: 7 cm/km) and the Tisza (length: 590 km; average flow: 800 m^3/s; the fall in the Hungarian section: 38 m; average: 6.4 cm/km). The navigability is limited mainly in the case of the Tisza River. Lake Balaton (594 km2) is the largest lake in Central Europe and Lake Héviz (47.5 km^2) is the largest thermal lake in Europe.[6]

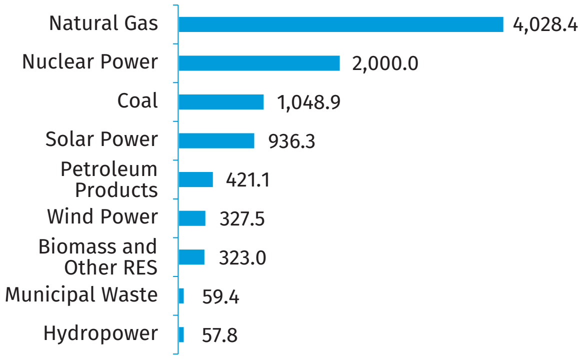
ELECTRICITY SECTOR OVERVIEW

The electricity generation mix is composed of nuclear power, coal (lignite), natural gas, petroleum products, renewable sources (solid biomass, biogas, wind, solar, hydropower, geothermal, municipal waste). Gross electricity generation amounted to 34,154 GWh in 2019, with nuclear power accounting for almost 48 per cent, natural gas 25 per cent, coal 12 per cent, biomass 5 per cent, solar power 4 per cent, wind power 2 per cent, biogas 1 per cent, hydropower 1 per cent, municipal waste 0.4 per cent, petroleum products 0.2 per cent, geothermal power below 0.1 per cent and other sources (blast furnace, coke oven gas, tail gas, non-renewables waste) 1 per cent (Figure 1).[7]

All rural and urban areas of the country (100 per cent of the total population) have access to the electricity supply.[9] It should be mentioned that approximately 28 per cent of consumed electricity was imported in 2018.[10] Moreover, the country faces a need for efficiency measures as well as for new generating capacities, which are mainly to replace old power plants.[11] There is one state-owned nuclear power plant located near the town of Paks, Paksi Atomerőmű. This power plant accounted for almost 50 per cent of the domestically generated electricity in 2019. The Paks power plant is composed of four reactors with a total gross capacity of 2,000 MW.[8] These units have been approved for a lifetime extension of 20 years until 2032, 2034, 2036 and 2037, respectively.[12] In 2017, the European Commission approved funding for the construction of the Paks2 nuclear power plant. Two new reactors, each with an installed capacity of 1,200 MW, will replace the four currently operating units of 500 MW that were installed in the 1980s.[13] The new reactors are expected to be commissioned in 2026–2027. The Government considers the Paks2 project strategic for replacing the old plants and reducing the country's import dependence. However, without uranium mines in Hungary, all the nuclear fuel will have to be imported.

In 2019, electricity generation from gas and coal accounted for approximately 25 per cent and 12 per cent of total generation, respectively. The Mátrai Erőmű, a lignite-based power plant with an installed capacity of 940 MW, is the second-largest power plant in the country.[8] The Paks nuclear power plant and the Mátrai power plant combined accounted for nearly 60 per cent of the electricity generated in the country in 2019. At the same time, renewable energy sources combined contributed approximately 14 per cent of total generation. Among renewable energy sources, only the solar photovoltaic (PV) installed capacity has grown significantly in recent years with a fourfold increase in electricity production between 2017 and 2019.[8]

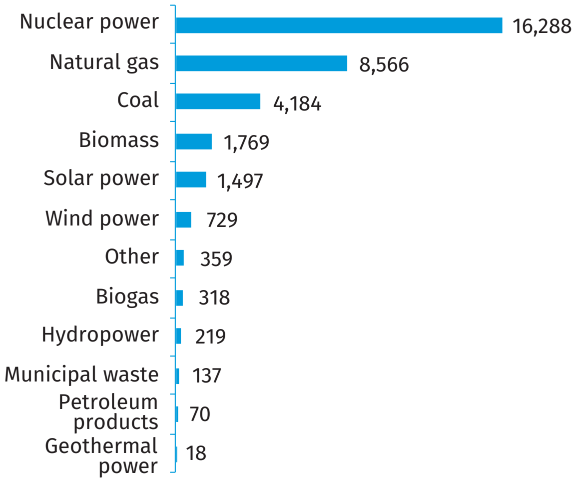
Figure 1. **Installed Electricity Capacity by Source in Hungary in 2019 (MW)**



Source: HEA[8]

The installed power production capacity at the end of 2019 was 9,202 MW, with 44 per cent coming from natural gas-fired power plants, 22 per cent from nuclear power, 11 per cent from coal-fired plants, 10 per cent from solar power, almost 5 per cent from oil-fired plants, 4 per cent from wind power, 4 per cent from biomass and other renewable energy (including biogas and geothermal power), 0.6 per cent from municipal waste and 0.6 per cent from hydropower (Figure 2).[8] Thus, in 2019 renewable energy sources combined accounted for roughly 19 per cent of the total installed capacity.

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



Source: HEA[8]

The installed capacity of solar PV systems is expected to reach 3,000 MW by 2023 and 6,500 MW by 2030 according to the National Energy and Climate Plan.[11] The wind power capacity has not increased since 2010. Since 2016 all wind power developments have been banned by law in Hungary. The reason for the ban is currently unclear. Typical arguments include the lack of wind resources and the undesirable appearance of turbines in the landscape. However, the fact that wind turbines currently operate in the country is an example that contradicts this argument. What could be in the background of the decision is that cheap wind energy would be a competitor for the Paks2 nuclear project.[14]

Based on the European Union (EU) regulations on the single energy market, Hungary effectuated ownership unbundling as well as the creation of a national regulatory sector and an Agency for the Cooperation of Energy Regulators. This means that in Hungary power plants can be privately owned and producers can sell their electricity directly to customers or on the wholesale market, although the prices for universal suppliers are still regulated.[15] The Hungarian Energy and Public Utility Regulatory Authority (HEA) is the market regulatory body, whose main tasks include licence issue and ratification of the grid fees for transmission and distribution system operators.[16]

The state-owned MAVIR is the only transmission system operator (TSO) in Hungary. There are six distribution system operators (DSOs): E.ON South-Donau DSO, ÉMÁSZ DSO, E.ON North-Donau DSO, NKM Electricity Supplier DSO (state-owned), ELMÜ DSO, and E.ON Tisza-region DSO. In 2019, the total length of the Hungarian transmission network was 4,870 km and the total length of the distribution network was 163,854 km. In the same year, the maximum winter 15-minute peak load was 7,105 MW, while the maximum summer peak load was 6,633 MW.[8]

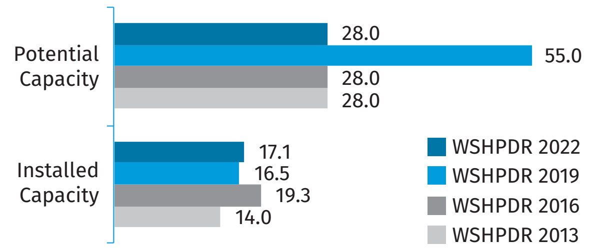
HUPX is the operator of the Hungarian day-ahead and intraday power exchange market.[17] Hungary is part of the bidding zone for the wholesale market including the Czech Republic, Slovakia and Romania. End-user prices are regulated; therefore, network costs remain the only component of the final electricity price that varies, though only slightly, across the country depending on the DSO responsible for the region. The HEA determines the network tariffs for transmission and distribution and sets universal service prices on an annual basis.

Electricity prices are set for households and small enterprises and, therefore, do not vary significantly across the country. Gradual price cuts have been realized by the Government in recent years aiming to ensure affordable electricity for all residential customers. According to the comparison of residential customer prices in the EU as of October 2020, the average price that a typical Hungarian household customer paid was 0.1063 EUR/kWh (USD 0.13/kWh), which was one of the lowest in the EU.[18] However, considering the average salaries as well, it can be stated that the sum that Hungarian households pay for electricity accounts for a relatively high share of income compared to other EU countries.[19] On the other hand, household customers do not bear the costs of supporting mechanisms for renewable electricity.

SMALL HYDROPOWER SECTOR OVERVIEW

Small hydropower (SHP) is defined by Hungarian regulation as hydropower plants with an installed capacity of 5 MW or less.[20] A total of 28 SHP plants with a generation capacity of up to 5 MW were operating in the country at the end of 2019, adding up to an overall installed capacity of 17.1 MW (Figure 3).[21] The average installed capacity of these SHP plants was 0.6 MW. Combined, the SHP plants produced approximately 68 GWh of electricity in 2019. The economic potential capacity for SHP in the country is currently estimated at 28 MW.[20] The total technical potential capacity for SHP plants was previously estimated at 55 MW with an annual generation of 300 GWh.[22] Compared to the results of the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity of SHP in Hungary increased slightly, by 0.6 MW. One reason is the refurbishment of the Gibárt SHP plant (total capacity 0.49 MW), which increased the capacity of the plant by approximately 70 per cent.[23] A new SHP plant with an installed capacity of 0.31 MW was also built in Szentgotthárd. Conversely, the SHP potential has decreased due to the use of the economic potential estimate in the current edition compared to the technical potential estimate used in the previous one.

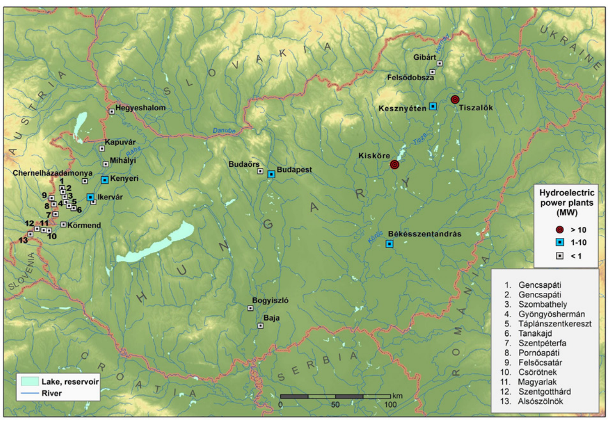
Figure 3. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in Hungary (MW)**



Source: MND,[20] Munkácsy & Campos,[21] *WSHPDR 2019*,[22] *WSHPDR 2013*,[24] *WSHPDR 2016*[25]

Note: The SHP potential estimate in the *WSHPDR 2019* referred to the technical potential.

Figure 4. **Hydropower Plants Operating in Hungary in 2019**



Source: Munkácsy & Campos[21]

Note: Map edited by Csüllög, G.

There are also two hydropower plants with an installed capacity above 10 MW in Hungary; one is located in Kisköre (28 MW) and one in Tiszalök (12.9 MW) (Figure 4). Table 1 presents the main attributes of some operational SHP plants. All 28 SHP plants are connected to the electricity grid.

Due to the relatively unfavourable natural conditions, such as the mountainous terrain and spatial and temporal differences in the distribution of rainfall in the country, the total hydropower potential in Hungary can be considered modest. Nevertheless, development opportunities do exist, particularly for plants of up to 5 MW.[20] However, no detailed feasibility studies are available to identify SHP projects most suitable for investment.

The Hungarian hydropower tradition dates back to 1896 when the first plant was built on the Rába River near Ikervár. Some SHP plants are more than 100 years old, such as the two on the Hernád River (located near Gibárt and Felsődobsza). Refurbishments have been performed over the years and these plants are still operating. These hydropower plants are important landmarks and constitute part of the culture of small villages. SHP plants are also considered environmentally friendly and have some level of acceptance by the public. New projects are rare, which can be explained by the fact that most feasible sites have already been developed.

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

Name	*Location*	*Capacity (MW)*	*Head*	*Plant type*	*Turbine type*	*Operator*	*Launch year*
Alsószölnöki vízerőmű	Alsószölnök (Rába)	0.250	3.00	Run-of-river	Francis		1960
Békésszentandrási vízerőmű	Békésszentandrás (Körös)	2.034	4.85	Run-of-river	Kaplan	Hydro Power Consulting Magyarország Tanácsadó Kft.	2013
Csörötneki vízerőmű	Csörötnek (Rába)	0.485	3.50	Run-of-river	Francis	Szombathelyi Vízerőmű Kft	1919
Damonyai vízerőmű	Damonya (Pinka)	0.025	1.80	Run-of-river	Francis		1951
Felsőcsatári vízerőmű	Felsőcsatár (Pinka)	0.090	3.50	Run-of-river	Francis		1950
Felsődobszai vízerőmű	Felsődobsza (Hernád)	0.948	3.00	Run-of-river	Kaplan	ALTEO Group	1911

Name	*Location*	*Capacity (MW)*	*Head*	*Plant type*	*Turbine type*	*Operator*	*Launch year*
Gibárti vízerőmű	Gibárt (Hernád)	0.490	4.40	Run-of-river	Francis	Észak-magyarországi Áramszolgáltató Nyrt.	1903
Kapuvári vízerőmű	Kapuvár (Rába)	0.175	2.70	Run-of-river	Francis		1968
Kenyeri vízerőmű	Kenyeri (Rába)	1.542	4.40	Run-of-river	Kaplan	Kenyeri Vízerőmű Kft.	2008
Körmendi vízerőmű	Körmend (Rába)	0.400	4.10	Run-of-river	Francis	Szombathelyi Vízerőmű Kft	1930
Lukácsházai vízerőmű	Lukácsháza (Gyöngyös)	0.022	3.20	Run-of-river	Francis		1952
Pornóapáti vízerőmű	Pornóapáti (Pinka)	0.260	4.20	Run-of-river	Francis		1951
Szentgotthárdi vízerőmű	Szentgotthárd (Rába)	0.310	4.00	Run-of-river	Archimedean screw	Charpatia Vízerőmű Kft.	2017
Szentpéterfai vízerőmű	Szentpéterfa (Pinka)	0.110	3.7	Run-of-river	Francis		1951

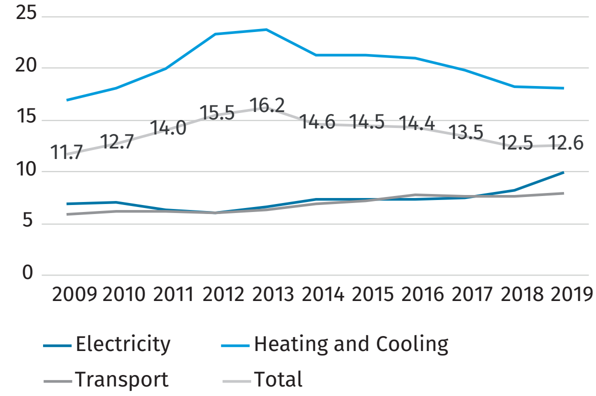
Source: Munkácsy & Campos,[21] OIM[26]

RENEWABLE ENERGY POLICY

The Ministry of Innovation and Technology is responsible for renewable energy policy, climate policy and energy efficiency programmes. The binding target set for Hungary by the Renewable Energy Directive 2009/28/EC (European Parliament and Council) was a 13 per cent share of renewable energy in final energy consumption by 2020. The National Renewable Energy Action Plan established 14.65 per cent as the target. The 13 per cent target was almost achieved in 2019 (Figure 5) with firewood having a significant share of the renewable energy sources in final energy consumption. However, it is estimated that a large amount of firewood is illegally cut which jeopardizes the sustainable use of this source.[27]

From 2020 onwards, the latest National Energy Strategy 2030 and the National Energy and Climate Plan constitute the basis of the Hungarian renewable energy policy.[9,28] The new renewable energy target for 2030 is a mere 21 per cent (in gross final energy consumption), which is far from the EU average of 32 per cent. The concept is based only on the large solar PV capacity extension. The hydropower installed capacity is not expected to change until 2040.

Figure 5. **Sectoral and Overall Shares of Renewable Energy Sources in Gross Final Energy Consumption, 2009–2019 (%)**



Source: HEA[7]

As mentioned, SHP plants are more accepted among the public and decision-makers, but the situation is different for large hydropower developments. One of the reasons is the controversial Gabčíkovo–Nagymaros Dams project between Hungary and Slovakia on the Danube River. The project was suspended due to environmental concerns and was only partly finished.[29] Pumped-storage hydropower is a recurring topic of discussion, but there are currently no official plans.

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

The licensing process for a new SHP plant development is composed of three main permission procedures. The first one is a construction permission, which is obtained from the local government. The second one is an environmental permission obtained from the regional environmental authority. Environmental impact assessment is needed if the SHP plant is planned in a protected natural area. Permission from the water resource authority is part of the construction and environmental permission procedures. The third permission is for grid connection and is obtained after an agreement with the DSO. Technical requirements may vary according to individual DSOs. The whole authorization process takes at least 12 months.

COST OF SMALL HYDROPOWER DEVELOPMENT

SHP development costs have a highly site-specific nature. Electromechanical equipment, design and connection to the grid are some factors influencing projects costs.[30] The total cost per unit of installed capacity for the majority of hydropower projects globally ranged from 600 USD/kW to 4,500 USD/kW in the period 2010-2019.[31] However, it is possible to find projects costs outside this range and some projects in Hungary are examples of these. Some costs of SHP refurbishment and new construction projects in Hungary are presented in Table 2. Among these developments, the most recent one is the Gibárt SHP plant with an expected production of 5.75 GWh/year.[31]

Table 2. **Cost of Refurbishment and Construction of Small Hydropower Projects in Hungary**

Location	*Installed capacity (MW)*	*Type of site*	*Year of completion*	*Cost*
Felsődobsza	0.948	refurbishment	2012-2013	0.95 million HUF/kW (4,318 USD/kW)
Gibárt	0.490	refurbishment	2020	2.45 million HUF/kW (8,221 USD/kW)
Nick/Kenyer	1.542	new	2008	1.30 million HUF/kW (6,311 USD/kW)
Szentgotthárd	0.310	new	2017	1.23 million HUF/kW (4,677 USD /kW)

Source: ALTEO,[32] NFM,[33] ALON[34]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

The METÁR system is a feed-in tariff (FIT) and feed-in premium system. It is a mechanism to support the integration of renewable electricity producers into the market, as well as to support the fulfilment of the country's renewable energy targets. The METÁR system is built on three pillars based on the installed capacity of the plant: 1) a FIT (50 kW–500 kW); 2) the so-called 'green premium' granted without tendering (0.5 MW–1 MW) and 3) a 'green premium' granted through tendering procedures (> 1 MW). As of early 2021, there had been one auction completed under the METÁR system and a second one was ongoing. With one exception, only solar PV projects were supported, namely 71 projects. The exception was one landfill gas application.[35]

As of 2020, FIT rates were 32.05 HUF/kWh (0.11 USD/kWh) for hydropower plants below 0.5 MW. SHP plants between 0.5 MW and 1 MW can apply for a premium above the reference market price without taking part in the tendering procedure. The premium tariff rates were 26.70–33.26 HUF/kWh (0.091–0.11 USD/kWh) for hydropower plants up to 1 MW in 2020.[36] New investments and existing hydropower plants that undergo significant refurbishment or developments costing more than 50 per cent of the original initial investment cost may also apply for the METÁR support system. SHP plants under 50 kW can be supported under a net-metering regime. The MÉTAR mechanism is financed by industrial electricity consumers proportionally to the amount of electricity purchased.[37]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

The prognosis for precipitation shows that the annual sum of precipitation may not change significantly in Hungary. However, summer precipitation is likely to decrease, while autumn and winter precipitation is likely to increase.[3] Changes in the runoff of rivers are expected to influence hydropower generation. While the potential generation may slightly increase at the global level by 2050, projections for Central Europe point to the opposite direction. A reduction in the order of 0.1 to 2.5 per cent of the technical potential is estimated by 2050.[38] It can therefore be concluded that the climate crisis will pose risk to SHP development in Hungary.

In a scenario of average temperature increases in the summer, electricity consumption could be affected, particularly considering the recent increase in air conditioning unit ownership. Heating electricity requirements in the country are likely to decrease due to an average increase in winter temperatures.[39] However, more factors need to be considered, such as the share of electricity in the heating energy mix and efficiency measures.

Thus, changes in the climate could also contribute to SHP development, however, there are no indications that new SHP will be preferred over other generation capacity choices.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

There are currently 28 operational SHP plants in the country adding up to 17.1 MW of installed generation capacity. Some refurbishment works have been completed, which have slightly increased the total installed capacity by 0.6 MW since the *WSHPDR 2019*.

Moderate water resources because of the plain-dominated topography and seasonal variations in the distribution of rainfall are limiting factors for hydropower development in Hungary. Two main barriers are identified for the SHP sector in particular:

- The National Energy and Climate Plan focus on expanding the capacity of the nuclear power plant. Moreover, the Plan focuses on solar PV technology among the renewable energy sources and does not propose new hydropower;
- The most suitable sites for SHP have already been developed.

The following factors are enablers for SHP development:

- The total economic potential of 28 MW has not yet been fully developed;
- The remaining technical potential is estimated at 38 MW.

Although the METÁR FIT system could be an enabler, it is currently unclear whether the system is effective in promoting SHP development because by 2021 only one auction had been completed and there have been no other hydropower projects proposed.

REFERENCES

1. Hungarian Central Statistical Office (2020). *Population 2008–2019*. Available at https://www.ksh.hu/docs/hun/eurostat_tablak/tabl/tps00001.html (Accessed 5 November 2020).
2. Barany, G. (2019). Hungary: Culture, History, and People. In *Encyclopaedia Britannica*. Available at https://www.britannica.com/place/Hungary (Accessed 5 November 2020).
3. National Meteorological Service *(2020). Temperature - General characteristics*. Available at http://www.met.hu/en/eghajlat/magyarorszag_eghajlata/altalanos_eghajlati_jellemzes/homerseklet/. (Accessed 7 December 2020).
4. Pongrácz, R., Bartholy, J. & Miklós, E. (2011). Analysis of projected climate change for Hungary using ensembles simulations. *Applied Ecology and Environmental Research*, 9(4), 387-398.
5. National Meteorological Service (2020). *Csapadék - Általános éghajlati jellemzés*. Available at http://www.met.hu/eghajlat/magyarorszag_eghajlata/altalanos_eghajlati_jellemzes/csapadek/ (Accessed 7 December 2020).
6. György, L. A. (2013). The impact of Holocene tectonics on hydrological processes on the Danube, Tisza and Drava rivers. *Földrajzi Közlemények,* 137(3), 248–256.
7. Hungarian Energy and Public Utility Regulatory Authority (HEA) (2020). *Annual Data*. Available at http://www.mekh.hu/annual-data (Accessed 5 November 2020).
8. Hungarian Energy and Public Utility Regulatory Authority (HEA) (2020). *Data of the Hungarian Electricity System 2019*. Available at http://www.mekh.hu/download/8/35/e0000/a_magyar_villamosenergia_rendszer_2019_evi_adatai.pdf (Accessed 26 January 2021).
9. Hungarian Central Statistical Office (CSO) (2019). *Housing and Public Utilities*. Available at http://www.ksh.hu/katalogus/#/kiadvanyok/tema/housing-and-public-utilities/en (Accessed 5 November 2020).
10. Hungarian Electricity Transmission System Operator (MAVIR) (2020). *Hungarian Electricity System Data 2019 Summary*. Available at https://www.mavir.hu/documents/10262/238749099/VER2019_Osszefoglalo_EN.pdf/ed030010-d7b2-049e-ef07-741b0bf25e6e?t=1592332680648 (Accessed 20 December 2021).
11. Ministry of Innovation and Technology (2019). *National Energy and Climate Plan*. Available at https://ec.europa.eu/energy/sites/ener/files/documents/hu_final_necp_main_en.pdf (Accessed 15 February 2021).
12. European Commission (2019). Hungary Paks Nuclear Power Plant. Available at https://ec.europa.eu/energy/sites/ener/files/art_35_technical_report_hu_19-02.pdf
13. NS Energy (n.d.). Paks II Nuclear Power Plant. Available at https://www.nsenergybusiness.com/projects/paks-ii-nuclear-power-plant/ (Accessed 22 February 2020)
14. Antal, M. (2019). How the regime hampered a transition to renewable electricity in Hungary. *Environmental Innovation and Societal Transitions*, 33m 162-182. Available at https://www.sciencedirect.com/science/article/pii/S2210422418300029
15. European Commission (2011). *Questions and Answers on the third legislative package for an internal EU gas and electricity market.* Available at https://ec.europa.eu/commission/presscorner/detail/de/memo_11_125 (Accessed 13 November 2020).
16. Hungarian Energy and Public Utility Regulatory Authority (HEA) (2020). *The authority*. Available at http://www.mekh.hu/home (Accessed 15 November 2020).
17. Hungarian Power Exchange (HUPX) (2020). *Members.* Available at https://hupx.hu/en/ (Accessed 15 November 2020).
18. Eurostat (2020). *Electricity prices for household consumers - bi-annual data (from 2007 onwards)*. Available at https://ec.europa.eu/eurostat/databrowser/view/nrg_pc_204/default/bar?lang=en (Accessed 5 November 2020).
19. Hungarian Energy and Public Utility Regulatory Authority (HEA) (2020). *International Comparative Study of Retail Electricity and Natural Gas Prices October 2020.* Available at http://www.mekh.hu/download/2/53/e0000/nemzetkozi_arosszehasonlitas_2020_oktober.pdf (Accessed 16 December 2020).
20. Ministry of National Development (MND) (2011). *Renewable Energy: National Renewable Energy action plan 2010 - 2020*. Deputy Secretariat of State for Green Economy Development and Climate Policy.
21. Authors' communication with HEA.
22. 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.
23. Alteo (2020). *Reconstruction of Gibárt Hydropower Plant Completed.* Available at https://bse.hu/newkibdata/128511636/ALTEO_Gibart_sajtokozelemeny_20201215_en.pdf (Accessed 22 February 2020)
24. 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.
25. 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.
26. OpenInfraMap (OIM) (2021). *All 199 power plants in Hungary.* Available at https://openinframap.org/stats/area/Hungary/plants (Accessed 20 December 2021).
27. Mezősi, A, Pató, Z & Szabó, L (2017). *Meg-megújuló statisztikák*. Regionális Energiagazdasági Kutatóközpont (REKK) - Regional Centre for Energy Policy Research.
28. Ministry of National Development (2013). *National Energy Strategy 2030*. Available at https://2010-2014.kormany.hu/download/7/d7/70000/Hungarian%20Energy%20Strategy%202030.pdf (Accessed 22 February 2020).
29. International Court of Justice (2017). *Gabčíkovo-Nagymaros Project (Hungary/Slovakia). Overview of the Case.* Available at https://www.icj-cij.org/en/case/92 (Accessed 22 February 2020).
30. International Energy Agency (IEA) (2020). *Projected Costs of Generating Electricity 2020.* Available at https://www.iea.org/reports/projected-costs-of-generating-electricity-2020 (Accessed 22 January 2021).
31. International Renewable Energy Agency (IRENA) (2020).

Hydropower. Available at https://www.irena.org/costs/Power-Generation-Costs/Hydropower (Accessed 22 January 2021).
32. Alteo (2017). *Hydroelectric power plant*. Available at https://alteo.hu/category/power-plants-en/hydroelectric-power-plant-en/?lang=en (Accessed 27 December 2021).
33. NFM (2009). *A Kenyeri vízerőmű*. Available at https://www.kenyerivizeromu.hu/cikkek/kenyerivizeromu.html (Accessed 27 December 2021).
34. ALON (2017). *A Békésszentandrási kisvízerőmű. Archimédeszi csigákkal működik egy erőmű Szentgotthárdnál*. Available at https://www.alon.hu/helyi-hirek/2017/06/hallott-mar-ilyenrol-archimedeszi-csigakkal-mukodik-egy-eromu-szentgotthardnal (Accessed 27 December 2021).
35. Hungarian Energy and Public Utility Regulatory Authority (HEA) (2020). *The HEA has published the results of the METÁR tender*. Available at http://www.mekh.hu/the-hea-has-published-the-results-of-the-metar-tender (Accessed 29 January 2021).
36. Hungarian Energy and Public Utility Regulatory Authority (HEA) (2021). *Renewable Support System (METÁR).* Available at http://www.mekh.hu/megujulo-tamogatasi-rendszer-metar (Accessed 16 December 2020).
37. Hungarian Energy and Public Utility Regulatory Authority (HEA) (2020). *Information on the Renewable Energy Support System (METÁR).* Available at http://www.mekh.hu/information-on-the-renewable-energy-support-system (Accessed 16 December 2020).
38. Hamududu, B. & Killingtveit, A. (2012). Assessing climate change impacts on global hydropower. *Energies*, 5(2), 305-322. https://doi.org/10.3390/en5020305.
39. Klein, D. R., Olonscheck, M., Walther, C. & Kropp, J. P. (2013). Susceptibility of the European electricity sector to climate change. *Energy*, 59, 183-193. http://dx.doi.org/10.1016/j.energy.2013.06.048.

Moldova

Nicolae Soloviov, Energy Efficiency Agency Moldova

KEY FACTS

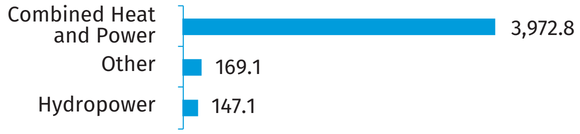
Population	2,643,883 (2020)[1]
Area	33,851 km^2 [2]
Topography	The relief of Moldova includes hills and flatland areas, with uplands mostly located in the central part of the country. The average altitude is 147 metres above sea level. The highest altitude is 429.5 metres at the Bălănești Hill and the minimum is at about 2 metres above sea level in the lower course of the Nistru River. The country's hills are part of the Moldavian Plateau, with altitudes varying between 240 and 320 metres. In the western area near Prut, there is a series of reefs, the so-called "taltra". In the south, the country has a small flatland, the Bugeac Plain.[3]
Climate	The Republic of Moldova is located in the temperate-continental zone, characterized by mild winters and long hot summers with low humidity. The continental climate is influenced by the Black Sea. Summers are hot with an average daytime temperature of over 24 °C in July, although highs can sometimes reach over 40 °C. Winters are mild with average daytime temperatures between -5 °C and -3 °C in January. [4]
Climate Change	In recent decades, increases in annual air temperatures have exceeded historical norms. Between 1981 and 2008, annual temperatures rose by approximately 0.58 °C per decade, compared with an average increase of 0.035 °C per decade between 1887 and 1980.[5] Additional climate change impacts have included droughts and major floods. These, along with the effects of rising average temperatures and the unequal distribution of rainfall throughout the year, have had negative consequences for the country's economy and the welfare and health of the population.[3] Climate change models predict a continuing rise of annual air temperatures in the country, with an increase of 1.7–2 °C by 2039 and of as much as 4.1–5.4 °C by 2099, relative to the baseline period of 1961–1990. Significantly, mean winter temperatures could increase from the baseline value of -2 °C to +2–4 °C by the 2080s.[5]
Rain Pattern	The territory of Moldova is characterized by insufficient humidity, with low and variable rainfall.[4] Annual precipitation is generally lower in the south-east of the country, at approximately 448 mm, and in the north-west it averages 596 mm. Precipitation falls mainly during the warm period of the year in the form of rain showers and only 10 per cent of annual precipitation falls in the form of snow.[6]
Hydrology	The hydrographic network of Moldova includes 3,621 rivers (of which 10 are over 100 km long), 57 lakes with a total area of 52.6 km^2 and approximately 3,000 reservoirs. The total length of the rivers in the country exceeds 16,000 km. The Dniester (Nistru) river is located on the borders of Ukraine and Moldova and has an annual discharge of approximately 10 km^3. Another river located on the border of Moldova and Romania is the Prut, with an annual discharge of 2.4 km^3. The main natural lakes are located on the Prut River watercourse. Small artificial lakes include the Costesti-Stinca reservoir on the Prut River (736 million m^3) and Dubasari Reservoir on the Nistru River (277 million m^3). The average density of the hydrographic network in the country is 0.48 km/km^2. The main water sources are the Dniester River (comprising 54 per cent of all water resources in the country), the Prut River (16 per cent), groundwater (23 per cent) and other surface water sources (7 per cent).[3]

ELECTRICITY SECTOR OVERVIEW

The electricity sector in Moldova is dominated by combined heat and power (CHP), including plants running on coal, natural gas and oil as well as certain biofuels. The total installed capacity in the country was 2,999 MW in 2020, with the CHP plants accounting for 2,850 MW or approximately 95 per cent of the total capacity. Many CHP units can operate based on different fuels: oil can be used in 2,778 MW of installed capacity, natural gas in 2,383 MW and coal in 1,600 MW. In addition to CHP, hydropower provided 62 MW and other sources including renewable energy sources (RES) provided 87 MW (Figure 1).[7,8]

Electricity deliveries to the distribution network in Moldova in 2020 equalled 4,289 GWh, of which 3,972.8 GWh (93 per cent) were provided by CHP, 147.1 GWh (3 per cent) by hydropower, and 169.1 GWh (4 per cent) by other sources, including 167.2 GWh imported from Ukraine (Figure 2).[7,8]

Figure 2. **Electricity Delivered to the Grid by Source in Moldova in 2020 (GWh)**

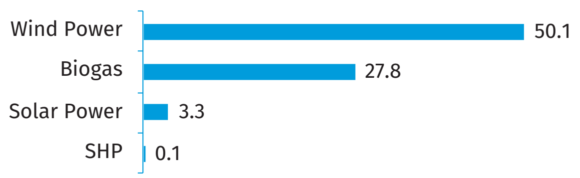


Source: Moldelectrica,[7] Moldelectrica[8]

Note: Electricity deliveries to the grid from RES other than hydropower not included due to conflicting data.

Electricity generation from RES in 2020 amounted to 81.3 GWh, with wind power accounting for 50.1 GWh (62 per cent) of the total, biogas producing 27.8 GWh (34 per cent), solar power contributing 3.3 GWh (4 per cent), and small hydropower (SHP) contributing approximately 0.1 GWh (less than 1 per cent) (Figure 3).[9]

Figure 3. **Annual Electricity Generation by Renewable Energy Sources in Moldova in 2020 (GWh)**



Source: ANRE[9]

Electricity consumption in Moldova has been steadily increasing in recent years, driven primarily by increasing household consumption of electricity. In 2020, country-wide electricity consumption reached 3,866.2 GWh, decreasing by approximately 0.2 per cent from 3,875.1 GWh in 2019. Consumption by households increased by 3.5 per cent, from 1,663.2 GWh in 2019 to 1,721.3 GWh in 2020. Consumption in rural areas grew by 4.1 per cent, from 804.0 GWh in 2019 to 837.3 GWh in 2020. Finally, consumption in urban areas grew by 2.9 per cent, from 859.2 GWh in 2019 to 883.9 GWh in 2020. At the same time, electricity consumption by non-household consumers decreased by 3.0 per cent, from 2,211.8 GWh in 2019 to 2,144.9 GWh in 2019.[9] Imports of electricity equalled 167.2 GWh in 2020.[7] As of 2019, the electrification rate in Moldova was 100 per cent.[10]

The infrastructure of the energy grid of Moldova was built during the Soviet period, as part of a common system optimized for operation between the Soviet Union and neighbouring countries: Bulgaria, Hungary and Romania. As Moldova suffers from insufficient domestic electricity generation capacity, it uses interconnections with Ukraine and Romania to cover its electricity needs and to balance the energy system. These interconnections include 7 lines of 330 kV and 11 lines of 110 kilovolts (kV) of interconnection with Ukraine as well as 1 line of 400 kV and 4 lines of 110 kV of interconnection with Romania.[11] According to Government Decision No. 102 of 5 February 2013 on the Energy Strategy of the Republic of Moldova until 2030, one of the objectives for the period 2013–2030 is to strengthen bidirectional transmission connections between the Integrated Power System/United Power System (IPS/UPS) and the European Network of Transmission System Operators of Electricity (ENTSO-E), allowing the Republic of Moldova to become an energy transit country.[11]

The National Agency for Energy Regulation (ANRE), established by Government Decision No. 767 of 11 August 1997, is the national energy regulatory authority of Moldova. ANRE is an independent entity directly subordinate to the Parliament. It implements state energy policy, sets energy tariffs including those for electricity and ensures the regulation and monitoring of the energy market.[12]

Tariffs for electricity for the years 2001–2019 are displayed in Table 1. While the prices have generally seen an upward trend when denominated in the national currency, the primary factor driving fluctuations in electricity prices in Moldova has been the evolution of the exchange rate of the national currency (MDL) to the US dollar used for the purchase of imported energy.

Table 1. **Electricity Tariffs in Moldova in 2001–2019**

Electricity price excluding VAT (MDL/kWh (USD/kWh))	*2001*	*2005*	*2010*	*2017*	*2018*	*2019*
Red Nord	0.63 (0.05)	0.70 (0.06)	1.43 (0.12)	1.93 (0.10)	1.79 (0.10)	2.02 (0.12)
Red Nord-West	0.68 (0.05)	0.70 (0.06)	1.43 (0.12)	2.04 (0.10)	1.79 (0.10)	2.02 (2.02)
Premier Energy (RED UF)	0.68 (0.05)	0.78 (0.06)	1.33 (0.11)	1.85 (0.09)	1.73 (0.10)	1.77 (0.10)

Source: ANRE[9]

Note: USD tariffs based on the average exchange rates current for the given year.

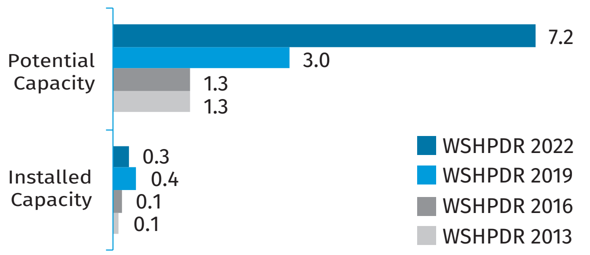
SMALL HYDROPOWER SECTOR OVERVIEW

There is no official definition of small hydropower (SHP) in the Republic of Moldova.[13] For the purposes of this chapter, SHP is defined as hydropower plants of up to 10 MW capacity.

As of 2021, there was only one SHP plant operating in Moldova, the SRL Hidroelectrica SHP plant on the Răut River with an installed capacity of 254 kW (Table 2). The plant has been allotted a tariff of 1.99 MDL/kWh (USD 0.11/kWh) for delivery of electricity to the grid.[14] The plant was constructed in 2017 on the site of a former water facility that had been abandoned since the 1960s. The plant's construction sparked controversy over the possibility that it had caused the significant decrease in water levels in the Răut River observed the same year.[15,16]

There are no recent nation-wide estimates of SHP potential in Moldova. However, a pre-feasibility study presented in 2016 identified a technically feasible SHP potential of approximately 7 MW on the Răut River.[17] Taking this estimate into consideration in addition to the known potential sites on other rivers, total potential capacity can be estimated to be at least 7.20 MW. Of this total, existing and previously operational SHP sites as well as those under consideration for SHP construction account for 2.17 MW. Figure 4 displays the installed and potential capacities of SHP in Moldova relative to previous editions of the *World Small Hydropower Development Report (WSHPDR)*. The decrease in installed capacity and increase in SHP potential relative to the *WSHPDR 2019* represent a more accurate interpretation of the available data, as no changes have taken place in practical terms.[14,17,18,19]

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



Source: AAE,[14] Pleșca, Pleșca, & Pleșca,[17] Ambros & Ursatii,[18] *WSHPDR 2019*,[19] *WSHPDR 2013*,[20] *WSHPDR 2016*[21]

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

Name	*Location*	*Capacity (kW)*	*Head*	*Plant type*	*Operator*	*Launch year*
SRL Hidroelectica	Telenești District, Brînzenii Noi	254	N/A	Run-of-river	SRL Hidroelectica	2017

Source: AAE[14]

In the 1960s, as many as 17 SHP plants were operational in Moldova and another 20 were planned for construction on various small rivers. However, all of these plants were dismantled or abandoned following the construction of large hydropower plants at Dubasari and Costeşti. Several of these non-functional micro-hydropower plants, with a combined capacity of 141 kW, remain in a serviceable state but require refurbishment. Identifiable former SHP sites that could potentially host new SHP projects also exist, with a total potential capacity of 575 kW. Proposals for new sites have been few, but a project involving several SHP plants was recently considered for a location near Trebujeni on the Răut River, with a potential capacity of 1.2 MW (Table 3).[13,14,18]

Table 3. **List of Selected Potential Small Hydropower Projects in Moldova**

Name	*Location*	*Potential capacity (kW)*	*Type of site*
Trebujeni	Răut River	1,200	New
Piatra/Jeloboc	Răut River	2 x 90	Reconstruction
Căzăneşti	Răut River	150	Reconstruction
Brânzeni	Răut River	126	Reconstruction
Vărvăreuca	Răut River	2 x 30	Refurbishment
N/A	Camenka River	57	Reconstruction
Vatra	Bâc River	2 x 22	Refurbishment
Vadul Turcului	Beloci River	32	Reconstruction
Ciuhur	Ciuhur River	30	Reconstruction
Corjeuţi	Lopatnic River	27	Refurbishment
CTŞ „Hidrotehnica”	Târnova	2 x 5	Refurbishment

Source: Ambros & Ursatii[18]

Overall, the rehabilitation of old SHP plants presents the most straightforward route to taking advantage of the existing SHP potential in Moldova and the most likely to be adopted by the private sector. Evaluations of the potential for the rehabilitation of old SHP plants and construction of new plants on the Răut River allow for the operation of approximately 20 mini-hydropower plants, with the average head of each plant at approximately 3 metres. The first hydropower plants recommended for rehabilitation are the ones in Piatra and Trebujeni, with a head of 4–5 metres and a potential capacity of 200–300 kW each.[17]

RENEWABLE ENERGY POLICY

In 2010, the Republic of Moldova became a full-fledged member of the Energy Community, committing itself to unifying its legal framework with the core European Union (EU) energy legislation and the so-called energy “acquis communautaire”, the total body of EU law applicable to Member States.[22]

The National Development Strategy “Moldova 2030”, adopted on 26 November 2018, outlined the need for economic development in line with principles of environmental security and sustainable use of natural resources.[23] In recent years, the Government has approved several pieces of legislation in support of these goals, including the following:

- Government Decision No. 698 of 27 December 2019 on the approval of the National Energy Efficiency Action Plan for 2019–2021;
- Government Decision No. 45 of 30 January 2019 on the organization and functioning of the Agency for Energy Efficiency;

- Law No. 139 of 19 July 2018 on energy efficiency;
- Government Decision No. 690 of 11 July 2018 on the Approval of the Regulations regarding the organization of tenders for offering the status of an eligible producer;
- Decision of the Board of Directors of ANRE No. 375/2017 of 28 September 2017 on the Methodology for determining fixed tariffs and prices for electricity produced by eligible producers from renewable energy sources;
- Law No. 10 of 26 February 2016 on the Promotion of the Use of Energy from Renewable Sources;
- Government Decision No. 301 of 24 April 2014 regarding the approval of the Environmental Strategy for 2014–2023 and of the Action Plan for its implementation;
- Government Decision No. 1073 of 27 December 2013 on the approval of the National Action Plan in the field of Renewable Energy for 2013–2020.

In March 2018, the Law on the Promotion of the Use of Energy from Renewable Sources entered into force.[24] The law transposes Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources. Capacity limits have been set in accordance with Government Decision No. 689 of 11 July 2018 regarding the approval of capacity limits, maximum quotas and capacity categories in the field of electricity from renewable sources until 2020 (Table 4).

Table 4. **Capacity Limits, Maximum Allowances and Capacity Categories for Renewable Energy Support Schemes in Moldova**

Technology	*Allotted capacity quota (MW)*			*Capacity limit (MW)*
	Total	*Using feed-in tariffs*	*Using fixed price established by tender*	
Wind power	100	20	80	4
Solar PV	40	15	25	1
Biogas	20	12	8	1
Cogeneration (using solid biomass)	5	5	0	1
Hydropower	3	3	0	1
Total	**168**	**55**	**113**	-

Source: Government of the Republic of Moldova[25]

The capacity limits are used to decide on the support schemes. Eligible producers can use one of the available support schemes: net metering or feed-in tariffs (FITs).[26] The net metering support scheme has been introduced to encourage project owners to cover their own electricity consumption with renewable energy–based production units with a maximum capacity of up to 200 kW, including hydropower. Any excess, calculated over a one-year period, may be sold at the average price of the wholesale energy market. In 2019, a total of 127 projects were put into operation in the country using this support scheme, with a total capacity of 1.49 MW, while in 2020 another 269 projects were put into operation with a total capacity of 4.90 MW. All these projects use solar photovoltaic (PV) installations.[9] Requirements for hydropower projects are specified in the tender announcements.

The methodology for calculating the FIT support scheme was approved by ANRE Decision No. 375 of 28 September 2017. Only power plants with capacities between 10 kW and the capacity limit defined by the Government are eligible for the FIT support scheme. Based on this methodology, the ANRE Board of Directors approved the following prices and fixed tariffs for electricity produced from renewable energy sources:

- Solar PV – 1.88 MDL/kWh (0.11 USD/kWh);
- Wind power – 1.55 MDL/kWh (0.09 USD/kWh);
- Hydropower – 0.97 MDL/kWh (0.06 USD/kWh);
- Biogas cogeneration – 1.84 MDL/kWh (0.10 USD/kWh);
- Solid biomass cogeneration – 1.96 MDL/kWh (0.12 USD/kWh).[27]

The FITs are annually adjusted to account for the variable exchange rate between the national currency and the US dollar.

In 2020, the procedure for the selection of producers eligible for the fixed FIT support scheme was announced for the first time. As a result, 27 renewable energy power plants were certified for FITs as of 21 December 2020, including 20 solar PV power plants, 6 wind power plants and 1 plant based on biogas cogeneration.[28]

According to Law No. 10/2016 regarding the promotion of energy use from renewable sources, the Government will adopt a tender/auction system for the selection of renewable energy projects. The introduction of capacity tenders was tentatively scheduled for 2019 but did not take place. The tenders are planned to be organized by a commission appointed by the Government in accordance with the provisions of Article 35 Paragraph 2 of the aforementioned Law.[24]

SHP development is regulated by the same legislation as other renewable energy sources. Similarly, SHP plants are eligible for the support schemes of net metering, FITs and tenders/auctions. Development of renewable energy projects in Moldova involves the following steps:

- Establishing a company and registering property rights (if necessary);
- Changing the land designation from agricultural land to land for construction purposes and obtaining an Urban Planning Certificate for Design Documentation;
- Developing technical conditions for connecting to utility networks as well as a Networks Routing Plan, conducting a topographical study and geotechnical prospecting, obtaining an Environmental Permit and carrying out an Environmental Impact Assessment;

- Preparing a detailed technical design and obtaining its verification and approval;
- Obtaining an authorization for construction;
- Registering with the fixed price or the fixed tariff support scheme;
- Obtaining approval to build a new renewable energy power plant and notifying the Agency for Technical Supervision of the launch of construction;
- Following construction and connection to the power transmission or distribution network, conducting post-construction assessments and obtaining approval of completed works;
- Obtaining a power generation licence;
- Signing an electricity supply contract;
- Registering the licence with the system operator and entry into force of the electricity supply contract and beginning of the operational phase.[29]

COST OF SMALL HYDROPOWER DEVELOPMENT

Development costs of SHP projects in Moldova are regulated by ANRE Decision No. 54/2020 of 28 February 2020 on fixed tariffs and prices for electricity produced from renewable energy sources. This document establishes the basic values used for calculating fixed tariffs and ceiling prices for electricity produced from renewable energy sources. For hydropower plants, the following coefficients and costs apply:

- Specific investment of 28,629 MDL/kW (1,662 USD/kW) — the maximum permissible cost per kilowatt of installed capacity of the commissioned SHP plant;
- Specific fixed maintenance and operating expenses of 3 per cent per year — the maximum permissible fraction of the total cost of the plant to be spent on maintenance and operation per year;
- Specific variable maintenance and operating expenses — no limit set, allowing the operators to decide the cap for these expenses on an individual basis;
- Capacity factor of 50 per cent, representing the minimum permissible value;
- Guarantee of participation of 54.7 MDL/kW (3 USD/kW) and guarantee of proper execution of 546.7 MDL/kW (30.4 USD/kW), representing a deposit submitted by the developer selected during the tender process. Following commissioning of the plant, the funds are unfrozen and accessible to the developer without conditions.[30]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

According to the Organisation for Economic Co-operation and Development (OECD) Small Business Act Moldova country profile, some progress has been made between 2012 and 2021 in providing support to and increasing the competitiveness of small and medium-sized enterprises (SMEs) in the country.[31] Despite these efforts, there remain limitations in terms of public support for SMEs, including SHP plants, with regard to innovation, greening and access to both bank and non-bank finance. Local commercial banks are cautious about investing in the renewable energy sector, due to their perception of such projects as high-risk, which partly stems from the general limited understanding of renewable energy technologies. As such, the main financing support comes from international financing institutions and local funds created with donor support.

The European Bank for Reconstruction and Development (EBRD), one of the major investors in the energy sector in Moldova, has implemented two programmes to support local energy projects: Moldovan Sustainable Energy Financing Facility II (MoSEFF II) and Moldovan Residential Energy Efficiency Financing Facility (MoREEFF). These projects provided credit lines to local banks for the re-accreditation of energy efficiency projects and sustainable investments in the energy sector. Additionally, in 2020 the EBRD and the Green Climate Fund (GCF) began promoting green finance in the country. Support for green technologies in Moldova includes a recent EUR 5 million (USD 5.95 million) loan provided by the EBRD and the Covenant of Mayors.[32]

The Covenant of Mayors, the world's largest initiative for local climate and energy actions, has been active in Moldova since 2009. Sixty-two municipalities in the country had signed the covenant as of 2020, committing themselves to submitting a Sustainable Energy and Climate Action Plan (SECAP) within two years of signing, of which 22 have additionally committed themselves to reducing municipal CO_2 emissions by 30 per cent by 2030. With this goal in mind, a total of EUR 970 million (USD 1,154.89 million) in investments is planned in various sectors in Moldova, of which 26 per cent is to be allocated towards local electricity production from renewable energy sources.[33,34]

The Energy Efficiency Agency (AEE) is a key local stakeholder in implementing state policy, national strategies and programmes in the energy efficiency and renewable energy in Moldova. Following an institutional reform in 2018, the AEE has been responsible for providing financial support to the sector — in part through funds allocated from the state budget, but also through additional funds to be raised on local, regional and international financial markets.[35]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

The negative impacts of climate change present challenges for the country's economic development, directly and indirectly affecting the sectors based on natural resources such as energy, transport and industry. Of particular relevance to hydropower is the precarious nature of the country's surface water resources. Analysis of national climatic data indicates that the 10-year drought frequency in Moldova is approximately 1–2 droughts in the north of the country, 2-3 droughts in the centre and 5–6 droughts in the south.

Projections of changes in runoff in the lower part of the Dniester River basin, which includes most of the territory of Moldova, estimate decreases of up to 25 per cent in both average and minimum runoff by 2050, relative to the baseline period 1971–2000. Even without significant changes in runoff, increasing temperatures and drought frequency will likely drive water demand from the agricultural sector up.[36] This might put additional pressure on the water resources available for hydropower.

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

In recent years, Moldova has intensified its efforts to develop renewable energy sources, with a focus on the adoption of new support schemes for renewable electricity generation. This has significantly contributed to the growing interest in renewable energy sources from local and international investors. However, further efforts are needed to remove barriers to the implementation of renewable energy projects in the country, particularly with regard to SHP, including the following:

- Financial barriers: Lack of long-term funding, together with high cost of capital and collateral guarantees;
- Technical barriers: Lack of local technologies required for SHP projects, leading to a dependence on high-cost imports;
- Lack of capacity: Technical capabilities, experience and knowledge are limited. The lack of technical skills is further compounded by the fact that the necessary technologies are not used and promoted in the country.

A number of factors encouraging the development of SHP in Moldova also exist. These include:

- Political: The legal framework necessary for SHP development, including laws, regulations and procedures, is well-developed and mature;
- Social: SHP projects have a low profile in the country due to lack of development and do not face significant social opposition;
- Market: The energy sector is growing constantly and electricity consumption is increasing in all the main sectors of the economy, driving demand for additional energy sources;
- Financial: Subsidies and support schemes for SHP are well-established and the current lack of SHP projects means that allocated quotas are still available. In addition, financing for renewable energy projects is potentially available from a number of international institutions.

REFERENCES

1. National Bureau of Statistics, Republic of Moldova (2020). *Population and demographic processes*. Available at https://statistica.gov.md/category.php?l=ro&idc=103& [in Romanian] (Accessed 25 February 2021).
2. National Bureau of Statistics, Republic of Moldova (2020). *Environment*. Available at https://statistica.gov.md/category.php?l=ro&idc=99& [in Romanian] (Accessed 25 February 2021).
3. Republica Moldova (n.d.). *Geography*. Available at https://moldova.md/ro/content/geografie [in Romanian] (Accessed 25 February 2021).
4. United Nations Economic Commission for Europe (UNECE) (2005). *2nd Environmental Performance Review of Republic of Moldova*. Available at https://unece.org/DAM/env/epr/epr_studies/moldova%20II.pdf (Accessed 13 June 2021).
5. Climate Change Post (n.d.). *Moldova*. Available at https://www.climatechangepost.com/moldova/climate-change/ (Accessed 13 June 2021).
6. State Hydrometeorological Service (SHS) (2019). *Characterization of weather and agrometeorological conditions in 2019*. Available at http://www.meteo.md/images/uploads/clima/year_rom.pdf [in Romanian] (Accessed 13 June 2021).
7. Moldelectrica (2020). *Energy sources*. Available at https://moldelectrica.md/ro/electricity/energy_sources [in Romanian] (Accessed 13 June 2021).
8. Moldelectrica (2020). *Technical and economic indicators of the transmission system operator for 2020*. Available at https://www.moldelectrica.md/ro/network/annual_report [in Romanian] (Accessed 13 June 2021).
9. National Energy Regulatory Agency (ANRE) (n.d.). *Report on the activity of the National Energy Regulatory Agency in 2020*. Available at https://www.anre.md/storage/upload/administration/reports/751/R%20A%20P%20O%20R%20T%20ANRE%202020%20Final.pdf [in Romanian] (Accessed 13 June 2021).
10. The World Bank (n.d.). *Access to electricity (% of population) – Moldova*. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=MD (Accessed 13 June 2021).
11. Government of Republic of Moldova (2013). *Decision no. 102 of 05.02.2013 on the Energy Strategy of the Republic of Moldova until 2030*. Accessible from http://lex.justice.md/ru/346670/ [in Russian] (Accessed 13 June 2021).
12. Energy Community (2016*). The National Energy Regulatory Authority of Moldova – Compliance, Governance, Independence and Performance*. Available at https://www.energy-community.org/dam/jcr:17635f1e-99ac-44e1-84eb-3b11e-a53841c/EnCS_NERA_Moldova.pdf (Accessed 13 June 2021).
13. State Hydrometeorological Service (2014). *March 22 – World Water Day*. Available at http://old.meteo.md/mold/22032014.htm [in Romanian] (Accessed 14 June 2021).
14. Energy Efficiency Agency (AEE) (2018). *Electricity distributed in the Republic of Moldova 2017*. Data not made available online.
15. ZdG (2017). *People and connections behind the hydropower plant on the Răut*. Available at https://www.zdg.md/investigatii/ancheta/oamenii-si-conexiunile-din-spatele-hi-

drocentralei-de-pe-raut/ [in Romanian] (Accessed 14 June 2021).
16. Moldpres State Information Agency (2017). *The decrease in water in the Răut was not caused by the activity of the mini-hydropower plant at Brânzenii Noi, says "Waters of Moldova"*. Available at https://www.moldpres.md/news/2017/09/22/17007298 [in Romanian] (Accessed 14 June 2021).
17. Pleșca, P., Pleșca, A., & Pleșca, R. (2016). *Hydropower potential of the Răut River in Moldova and the recovery scheme in the study of Professor Dorin Pavel.* 16th International Multidisciplinary Conference "Professor Dorin Pavel, founder of Romanian hydropower." Sebeș, 2016. Available at http://89.32.237.114/bitstream/handle/123456789/6242/plesca_257-266.pdf?sequence=1&isAllowed=y [in Romanian] (Accessed 21 June 2021).
18. Ambros, T. & Ursatii, N. (2015). *Some Aspects of Micro-HPP Utilization in the Republic of Moldova*. Available at https://journal.ie.asm.md/assets/files/12_03_29_2015.pdf [in Romanian] (Accessed 14 June 2021).
19. 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.
20. 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.
21. 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.
22. Energy Community (2020). *Moldova – annual implementation report*. Available at https://www.energy-community.org/implementation/Moldova.html (Accessed 21 June 2021).
23. Government of Republic of Moldova (2018). *National Development Strategy Moldova – 2030*. FAOLEX Database. Available at http://www.fao.org/faolex/results/details/en/c/LEX-FAOC191490/ (Accessed 21 June 2021).
24. Government of Republic of Moldova (2016). *Law on Promotion of the Use of Energy from Renewable Sources*. Available at http://lex.justice.md/index.php?action=view&view=doc&lang=1&id=363886 [in Romanian] (Accessed 21 June 2021).
25. Government of Republic of Moldova (2018). *Decision No. 689 of 11 July 2018, on the approval of capacity limits, maximum quotas, and capacity categories in electric power generation from renewable sources to 2020.* Available at https://www.legis.md/cautare/getResults?doc_id=108822&lang=ru [in Russian] (Accessed 21 June 2021).
26. Blajin, C. (2019*). Promotion in Moldova*. Legal Sources on Renewable Energy. Available at http://www.res-legal.eu/search-by-country/moldova/tools-list/c/moldova/s/res-e/t/promotion/sum/354/lpid/355/ (Accessed 21 June 2021).
27. National Energy Regulatory Agency (ANRE) (2020). *ANRE Approved fixed tariffs and ceiling prices for electricity produced from renewable energy sources*. Available at http://www.anre.md/anre-a-aprobat-tarifele-fixe-si-preturile-plafon-la-energia-electrica-produsa-din-surse-regenerabile-de-energie-3-101 [in Romanian] (Accessed 21 June 2021).
28. National Energy Regulatory Agency (ANRE) (2020*). Registry of eligible producers*. Available at http://anre.md/registrul-producatorilor-eligibili-3-339 [in Romanian] (Accessed 21 June 2021).
29. International Renewable Energy Agency (IRENA) (2019). *Renewables Readiness Assessment: Republic of Moldova. Annex. Key development steps for renewable energy projects in the Republic of Moldova.* Available at http://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_RRA_Moldova_2019_EN.pdf (Accessed 21 June 2021).
30. Government of the Republic of Moldova (2020). *The decision of the Board of Directors of the National Agency for Energy Regulation of the Republic of Moldova no. 54/2020 of 28 February 2020 on fixed tariffs and ceiling prices for electricity produced from renewable energy sources by producers who will obtain the status of the eligible producer in 2020*. Available at https://www.legis.md/cautare/getResults?doc_id=120978&lang=ru [in Russian] (Accessed 21 June 2021).
31. OECD et al. (2020). *SME Policy Index: Eastern Partner Countries 2020: Assessing the Implementation of the Small Business Act for Europe*. SME Policy Index, European Union, Brussels/OECD Publishing, Paris. Available at https://doi.org/10.1787/8b45614b-en (Accessed 21 June 2021).
32. European Bank for Reconstruction and Development (EBRD) (2020). *EBRD and GCF promote green financing in Moldova.* Available at https://www.ebrd.com/news/2020/ebrd-and-gcf-promote-green-financing-in-moldova.html (Accessed 21 June 2021).
33. Convenant of Mayors for Climate & Energy – East (2020). *Moldova*. Available at http://www.com-east.eu/en/about-us/covenant-of-mayors-east/moldova/ (Accessed 25 February 2021).
34. Convenant of Mayors for Climate & Energy – East (2020). *Plans and actions*. Available at http://www.com-east.eu/en/plans-and-actions/action-plans/ (Accessed 25 February 2021).
35. Government of Republic of Moldova (2019). *Decision no. 45 of 30.01.2019 on the organization and functioning of the Energy Efficiency Agency*. Available at https://www.legis.md/cautare/getResults?doc_id=112491&lang=ru [in Russian] (Accessed 21 June 2021).
36. Environment and Security Initiative (ENVSEC), United Nations Economic Commission for Europe (UNECE), Organization for Security and Co-operation in Europe (OSCE). (2015). *Incorporation of measures to adapt to climate change in the strategic documents of the Republic of Moldova*. Available at https://unece.org/fileadmin/DAM/env/water/meetings/NPD_meetings/Publications/2015/Strategic_Framework_for_Adaptation_to_Climate_Change_in_the_Dniester_River_Basin/Dniester_rus-WEB.pdf [in Russian] (Accessed 21 June 2021).

Poland

Ewa Malicka, Polish Association for Small Hydropower Development (TRMEW)

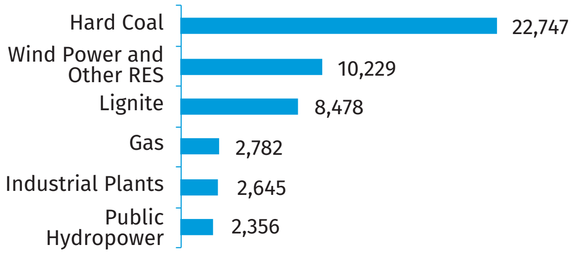
KEY FACTS

Population	38,354,173 (2020)[1]
Area	312,705 km^2 [2]
Topography	Poland is a lowland country with the majority of its land located lower than 300 metres above sea level. The highest point is Mount Rysy, at 2,499 metres above sea level. In Poland, there are four basic morphogenetic zones: the Carpathian Mountains with valleys, the old Sudetes with uplands, the area of central Poland and the littoral and lake regions. Most of the country's area is located in the Vistula and the Oder River basins. The Baltic Sea marks the northern border of the country and the ridges of the Carpathian Mountains and the Sudetes constitute its southern border.[3]
Climate	A border between the zones of moderate and subarctic climates and between oceanic and continental climates runs across Poland, causing a large amount of variability in its weather. Average annual temperature ranges between 6.5 °C and 8.5 °C. The coldest month is January, with average temperatures between -1 °C and -5 °C. The warmest month is July, with average temperatures between 16.5 °C and 18.5 °C. The number of days with temperatures below 0 °C in a year ranges between 90 and 130, although it is over 200 days in the mountains. The number of days with temperatures above 25 °C ranges between 5 and 40.[3]
Climate Change	Since the end of the 19th century, a systematic trend of rising temperatures has been observed in Poland, with a significant increase since 1989. The average yearly temperature in the years 1779–2000 was 7.7 °C, whereas for the two last decades of the 20th century and the first decade of the 21st century the average yearly temperatures were 8.7 °C, 8.9 °C and 9.2 °C for the respective three decades. Moreover, since 1989, several years recorded the highest average yearly temperatures since records began, including 2008 with an average temperature of 10.2 °C, 2000 with 10.0 °C and 1989 with 9.8 °C. The consequences of global warming observed in Poland include the intensification of extreme weather phenomena such as droughts, hurricane-force winds, tornadoes and hail, causing a noticeable change in the climate dynamics. Structural changes in precipitation have been observed in the warm seasons. Specifically, rainfall events have become both shorter and more extreme, with an elevated flood risk, while rainfall events below 1 mm per day are becoming rare. The results of analyses of climate scenarios for Poland in the 21st century show increasing temperatures across the country, extended periods without rainfall, increased number of maximum rainfalls and shorter snow cover periods. By 2071–2090, average annual temperature is expected to increase to 10.6 °C, while the average number of days per year with a maximum temperature of above 25 °C is expected to increase to 52, up from 27 in 1980–1991.[4]
Rain Pattern	The amount of precipitation depends on the region. It is highest in the mountains, with an annual average between 1,500 mm and 2,000 mm. In the valleys and uplands, it ranges from 400 mm to 750 mm, while the Wielkopolska region receives the lowest amount of rainfall (300 mm). The average rainfall in the whole country is approximately 600 mm, with the majority occurring in the summer months.[3]
Hydrology	Approximately 99.7 per cent of Poland belongs to the Baltic Sea drainage basin, which is in turn composed of the Vistula water basin (55.7 per cent), the Oder water basin (33.9 per cent) and the Neman water basin (0.8 per cent). Another 9.3 per cent constitutes the direct water basin of the Baltic Sea. The river network in Poland is asymmetrical with large water basins east of the Vistula and Oder Rivers, mainly because of its topographic slopes towards the north-west. The longest rivers are the Vistula (1,047 km), Oder (854 km), Warta (808 km) and Bug (772 km). Poland has approximately 9,300 lakes larger than 0.01 km^2, which altogether cover an area of 3,200 km^2 (approximately 1 per cent of the country's territory) and have a capacity of 17.4 km^3.[3]

ELECTRICITY SECTOR OVERVIEW

In 2020, the installed capacity in the National Electricity System of Poland was 49,238 MW, indicating a 5 per cent increase from 46,799 MW in 2019.[5,6] Thermal power (hard coal, lignite and gas) accounted for 34,008 MW (69 per cent of the total), wind energy and other renewable energy sources for 10,229 MW (21 per cent), industrial plants for 2,645 MW (5 per cent) and public hydropower plants for 2,356 MW (5 per cent) (Figure 1).[5]

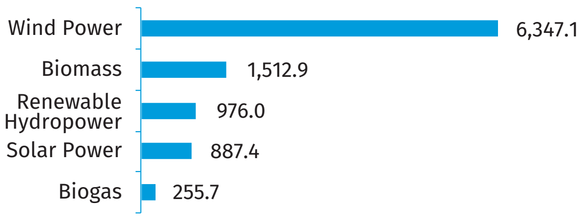
Figure 1. **Installed Electricity Capacity by Source in Poland in 2020 (MW)**



Source: PSE[5]

By the end of 2020, renewable energy capacity in Poland for installations enrolled in various support schemes (not including prosumers) reached 9,979 MW. Of this wind power supplied almost 64 per cent, biomass 15 per cent, renewable hydropower (hydropower plants generating electricity from the natural flow of water and excluding pumped storage plants) almost 10 per cent, solar power 9 per cent, and biogas 3 per cent (Figure 2).[7]

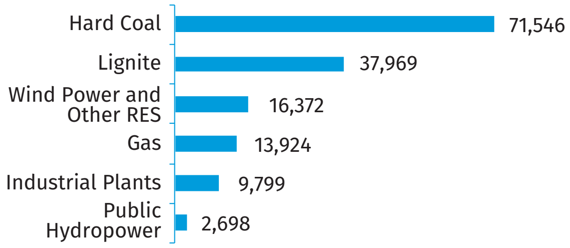
Figure 2. **Installed Renewable Energy Capacity by Source in Poland in 2020 (MW)**



Source: URE[7]

Total gross electricity generation in 2020 was 152,308 GWh and gross electricity consumption was 165,532 GWh.[5] The majority of generation in Poland is still based on conventional fuels, particularly hard coal and lignite. These contributed 72 per cent of total gross electricity generation in 2020 (Figure 3), though their share is decreasing year on year. In 2020, the share of energy from renewable energy sources in gross electricity consumption accounted for 11 per cent.[5] The electrification rate and grid availability in Poland is 100 per cent.[8]

Figure 3. **Annual Electricity Generation by Source in Poland in 2020 (GWh)**



Source: PSE[5]

The number and structure of electricity generating plants in Poland have not changed significantly over the last 5 years. In 2019, three companies, PGE Polska Grupa Energetyczna S.A., TAURON Polska Energia S.A. and ENEA S.A., held in total almost two-thirds of the country's installed capacity, provided almost 67 per cent of total electricity generation and over 66 per cent of the electricity fed into the grid.[6] Most of the power companies in the country continue to be owned by the State Treasury.

In Poland, there is one transmission system operator for electricity — PSE S.A, which is wholly owned by the State Treasury. PSE S.A.'s assets comprise the transmission grid, consisting of 281 lines of a total length of 15,316 km, 109 extra-high-voltage stations and a submarine 450 kV DC link between Poland and Sweden (254 km long).[9] In 2019, there were 189 distribution system operators (DSOs) involved in electricity distribution on the electricity market, including five large DSOs whose networks are directly connected to the transmission network. Large DSOs are legally obliged to separate the distribution activities carried out by the system operator from other activities not related to electricity distribution (unbundling).[6]

The biggest projects in the energy sector completed since 2018 include two new 900 MW coal-fuelled power plant units in Opole and one 910 MW unit in Jaworzno.[10] With regard to renewable energy, there is a noticeable increase in solar photovoltaic (PV) installations being put into operation, compared to the previous years. For example, between January 2020 and November 2020, the installed capacity of solar PV plants increased from 1,299.6 MW to 3,420.4MW.[11]

The ongoing development of the electricity sector includes an additional 20 GW of capacity either under construction or in the planning stages, represented primarily by coal- and gas-fired thermal plants. However, the ongoing projects also include one large hydropower plant on the Vistula River with a capacity of 80 MW, the country's first nuclear power plant with two units of 3,000 MW each and nearly 7,000 MW of offshore wind power plants located in the Baltic Sea.[10]

The Polish Energy Regulatory Office, an independent agency, is responsible for the regulation of the electricity, gas and heating markets. This includes licensing, approving investment plans by regulated companies, deregulation of the electricity and gas markets, oversight of the quality of supply and customer service as well as setting tariffs.[6]

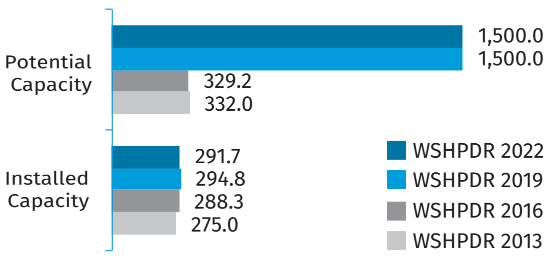
End users are entitled to receive electricity from a chosen supplier in an uninterrupted and reliable manner. In 2019, there were 5 default suppliers and 136 alternative trading companies actively selling electricity to final consumers. There are four electricity tariff groups in Poland. Groups A and B are for industrial users (supplied on the high- and medium-voltage grids), group C is for commercial users (connected to the low-voltage grid) and group G is for residential users. In 2019, there were 17.8 million consumers in the retail electricity market, out of which 91 per cent were in the G tariff group. Since 2008, the prices for companies using tariffs under groups A, B and C have remained unregulated, while the G tariff group (for households) is still subject to regulation. In the last quarter of 2019, the medium price of electricity in the retail market increased by 3.7 per cent as compared to the last quarter of 2016 as a consequence of the increase in costs of CO_2 emissions. It amounted to 477 PLN/MWh (130.3 USD/MWh), of which PLN 278 (USD 75.9) constituted the price of energy and PLN 199 (USD 54.4) constituted the distribution fee.[6]

SMALL HYDROPOWER SECTOR OVERVIEW

There is no official definition of small hydropower (SHP) in Poland; however, plants with a total capacity of up to 5 MW are customarily included in this category.[12] The operational definition of SHP used in the current chapter is up to 10 MW.

At the end of 2020, Poland had 782 renewable hydropower plants. Of these, 772 were SHP plants of up to 10 MW with a combined installed capacity of 291.7 MW (Table 1). Thus, SHP plants represented 30 per cent of the total hydropower capacity in the country in 2020. The installed capacity of SHP decreased by approximately 1 per cent relative to the *World Small Hydropower Development (WSHPDR) 2019*, whereas the potential has remained unchanged (Figure 4).[7,13,14,15] In 2020, electricity generation from SHP up to 10 MW was 949.7 GWh.[16]

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



Source: URE,[13] ESHA,[14] *WSHPDR 2019*,[15] *WSHPDR 2013*,[17] *WSHPDR 2016*[18]

The total theoretical hydropower potential of Polish rivers has been estimated to be 23.6 TWh/year, with a technical potential of 13.7 TWh/year.[19,20] Out of this, the technical hydropower potential of SHP (up to 10 MW) is estimated to be approximately 5 TWh/year, corresponding to at least 1,500 MW of potential installed capacity.[12,14] This indicates that less than 20 per cent of the country's technical SHP potential has been developed so far. It is also estimated that approximately 50 per cent (2.5 TWh or 735 MW) of this potential is economically feasible.[12,14]

Hydropower potential in Poland is characterized by an uneven distribution throughout the country with 68 per cent of resources concentrated in the Vistula River basin, half of which is located in the lower Vistula region and 17.6 per cent in the Oder River basin. The rivers with the largest hydropower potential are the Vistula, Dunajec, San, Bug, Oder, Bóbr and Warta. The most favourable regions for hydropower development are the south of Poland (mountainous areas) as well as the west and north (due to existing non-powered water infrastructure).[21]

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

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Plant Type*	*Operator*	*Launch year*
Bronocice	Nidzica River	0.037	2.7	Run-of-river	N/A	2015
Witulin	Świślina River	0.220	9.0	Run-of-river	N/A	2015
Brudnice	Wkra River	0.110	2.6	Run-of-river	N/A	2017
Słowik	Bobrza River	0.370	2.5	Run-of-river	N/A	2018
Świnna Poręba	Skawa River	4.400	N/A	Reservoir	PGW Wody Polskie	2019
Starogard Gdański	Wierzyca River	0.110	4.9	Run-of-river	N/A	2019
N/A	N/A	0.740	N/A	Run-of-river	N/A	2018-2020
N/A	N/A	0.132	N/A	Run-of-river	N/A	2018-2020
N/A	N/A	0.090	N/A	Run-of-river	N/A	2018-2020
N/A	N/A	0.498	N/A	Run-of-river	N/A	2018-2020
N/A	N/A	0.945	N/A	Run-of-river	N/A	2018-2020
N/A	N/A	0.499	N/A	Run-of-river	N/A	2018-2020
N/A	N/A	1.200	N/A	Run-of-river	N/A	2018-2020
N/A	N/A	2.100	N/A	Run-of-river	N/A	2018-2020
N/A	N/A	0.495	N/A	Run-of-river	N/A	2018-2020
N/A	N/A	0.090	N/A	Run-of-river	N/A	2018-2020

Name	Location	Capacity (MW)	Head (m)	Plant Type	Operator	Launch year
N/A	N/A	0.320	N/A	Run-of-river	N/A	2018-2020
N/A	N/A	2.400	N/A	Run-of-river	N/A	2018-2020

Source: TRMEW[22]

In the 1920s and 1930s, there were over 8,000 hydropower facilities in Poland, including many different types of mills and some hydropower plants. Only 2,131 of these installations remained by the 1980s, of which only 300 were in use at the time.[19] The possibility of repowering these historic sites is being considered as an economically feasible and environmentally sustainable form of small and micro-hydropower generation both by the Government and non-governmental organizations. The RESTOR Hydro Map, created through the Intelligent Energy Europe Programme of the European Union (EU), identifies over 8,500 historical sites in Poland as potential locations for small and micro-hydropower plants.[23]

Several planned SHP projects with a prospective launch date in 2023 are listed in Table 2. A selection of potential sites for future SHP investment is displayed in Table 3.

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

Name	Location	Capacity (MW)	Plant type	Developer	Planned launch year
N/A	Holy Cross Voivodeship	0.037	Run-of-river	Private	2023
N/A	Lesser Poland Voivodeship	0.110	Run-of-river	Private	2023
N/A	Warmian-Masurian Voivodeship	0.037	Run-of-river	Private	2023
N/A	Pomeranian Voivodeship	0.055	Run-of-river	Private	2023
N/A	Lubusz Voivodeship	0.075	Run-of-river	Private	2023

Source: TRMEW[22]

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

Name	Location	Potential capacity (MW)	Plant Type	Type of site (new/refurbishment)
N/A	Warmian-Masurian Voivodeship	0.045	Run-of-river	New
N/A	Masovian Voivodeship	0.055	Run-of-river	New
N/A	Lower Silesian Voivodeship	0.200	Run-of-river	New
N/A	West Pomeranian Voivodeship	0.075	Run-of-river	New
N/A	Opole Voivoideship	0.160	Run-of-river	New

Source: TRMEW[22]

RENEWABLE ENERGY POLICY

Although Poland refers to sustainable development in its constitution (Constitution of Poland, Article 5), the electricity sector is still largely based on carbon-intensive fossil fuels, and renewable energy sources do not play a significant role for decision-makers. At the EU level, Poland continuously opposes more ambitious greenhouse gas reduction targets and further developments of climate change policies, including the European Green Deal.[24] The main energy policy objective in the field of renewable energy sources, and the country's binding target based on the EU 2020 Climate and Energy Package, was to increase the share of renewable energy sources in total energy consumption to at least 15 per cent by 2020 and to further increase it in the following years. This initial target has been achieved, with the share of renewable sources in gross final energy consumption in Poland in 2020 (including the electricity, transport, heating and cooling sectors) slightly exceeding 16 per cent.[16]

The long-term energy strategy of Poland is determined by the Energy Policy of Poland until 2030 (adopted in 2009).[25] As of the moment of writing of this chapter, an updated long-term energy policy document, the Energy Policy of Poland until 2040, was under development, with its latest draft having been presented by the Minister of Climate and Environment on 8 September 2020.[26]

Until 1 July 2016, the support mechanisms for renewable energy sources were based on tradeable green certificates and an obligation of purchase of electricity by the appointed energy entities. On 20 February 2015, the Act on Renewable Energy Sources was adopted in Poland, introducing a support scheme based on tendering (auctions). In the new scheme, reference (maximum) prices are defined for each technology and additionally within each technology for installations with capacity up to 1 MW and for those above 1 MW. Likewise, auctions are conducted separately for existing and new installations with capacity of up to 1 MW and for those above 1 MW. Producers who win the tender have the right to receive the offered price for a period of 15 years.[27] Since 2015, there have been several amendments to the Act on Renewable Energy Sources. These introduced numerous changes in the support mechanisms, including options for micro-producers (prosumers) offering them discounts on electricity purchased from the grid in return for the electricity fed into the grid as well as in the tendering rules. Finally, in 2018 feed-in tariffs (FITs) and feed-in premiums (FIPs) were adopted for SHP and biogas plants, for both new and existing projects with an installed capacity below 1 MW.[28]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

The main regulations in Poland related to SHP include the Act on Renewable Energy Sources and the Energy Law (which outline rules of electricity production and support schemes for renewable electricity producers), the Water Law, the Water Basin Management Plans and the Conditions of Water Use in Water Regions (which outline rules of water management, water use for hydropower purposes, rules for water installations, requirements for residual flow, fish migration and some restrictions in developing new hydropower projects in line with the EU Water Framework Directive). Additional regulations include the Act on Nature Protection and the Act on Accessibility of Information concerning the Environment and its Protection, Participation of the Society in Protection of the Environment and Assessment of Impact on the Environment.

The licensing process for SHP in Poland consists of several steps. Firstly, the environmental impact of the project needs to be evaluated and an environmental decision needs to be obtained. Furthermore, a decision on building conditions is required, which is issued by the local administration, with the exception of rare cases where there is a spatial development plan covering the investment area. A water-legal assessment and permission need to be obtained from the water authority. The next important stage is to acquire rights to manage the real estate as a property of the State Treasury, including lands covered with running water and usually including the weir. These rights are acquired from the water authority which is responsible for the maintenance and ownership supervision over the estate. The finishing juncture of the procedure is to acquire a permit for construction through an application to the powiat (county-level) or the voivodeship (province-level) authority. Additionally, a decision on the terms and conditions of grid connection, and subsequently a grid connection agreement, must be obtained from the system operator in order to start operation. In Poland, nearly all SHP plants are connected to the grid and there are very few off-grid installations. Finally, the concession to produce electricity from a renewable energy source issued by the Energy Regulatory Office will be needed for plants with an installed capacity exceeding 500 kW. Installations with capacities of 50–500 kW require a registration as an electricity producer in small installation. In case of micro-producers, only a notification to the local system operator is required.[29]

COST OF SMALL HYDROPOWER DEVELOPMENT

The majority of hydropower plants in Poland fall into the categories of small and micro-hydropower. In 2020, out of a total number of 782 hydropower plants existing in the country, 704 were up to 1 MW. Many of them are low-head and located on small streams. These factors set Polish hydropower plants among projects with a very high levelized cost of energy (LCOE). In 2020, the average investment cost of SHP development in Poland was PLN 21.3 million (USD 5.82 million) per MW installed, while the average operational cost was 1.79 million (USD 0.48 million) per year per MW installed. In the same year, the costs of power generation (including CAPEX and OPEX) for newly developed projects amounted to PLN 735 (USD 201) per MWh produced, PLN 774 (USD 211) in the case of plants with an installed capacity below 500 kW and PLN 665 (USD 181) for those ranging from 500 kW to 1 MW.[30] In terms of older plants, after their depreciation and the expiry of the support period (15 years) the average cost of generation (OPEX only) in 2020 amounted to PLN 524 (USD 143) per MWh produced in the case of plants with an installed capacity below 500 kW and PLN 381 (USD 104) in the case of plants ranging from 500 kW to 1 MW.[31]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

Available funding options for SHP projects in Poland come from EU funds, the National Fund for Environmental Protection and Water Management, the Government of Norway (through the Green Industry Innovation Programme for Poland), the Rural Development Foundation and commercial banks.

Support schemes for new SHP projects include auctions, FITs and FIPs as well as discounts for prosumers in micro-installations. In 2020, the reference prices in auctions for hydropower amounted to PLN 620 (USD 170) per MWh for SHP plants with a capacity lower than 500 kW, PLN 560 (USD 153) per MWh for those with a capacity in the range between 500 kW and 1 MW and PLN 535 (USD 146) per MWh for hydropower plants with a capacity higher than 1 MW.[32] With the FITs and FIPs, which are the financial support schemes most commonly used by SHP producers, the guaranteed prices amount to 90 per cent of the reference prices assigned each year for auctions. Producers are entitled to the guaranteed price within auctions in either a FIT or a FIP for 15 years.[28]

The development of new projects has been difficult in recent years due to the gap between the closing of the green certificate system and the launch of new support schemes (auctions and FITs). As a result, between 1 July 2016 and 14 July 2018 there were no support schemes available for new hydropower projects.

Between mid-2018 and the end of 2020, several auctions were carried out for hydropower projects, but contracts were only won in auctions of hydropower plants with capacity higher than 1 MW (five contracts for new projects).[33] In the case of projects with lower capacities, there were not enough bids submitted as producers choose the FITs or FIPs instead. In 2018 and 2019, there were 343 existing SHP plants which switched from the certificate system or auctions to the FIT/FIP system, with a total installed capacity of 72 MW. At the same time, 15 permits were issued for new SHP projects to receive benefits from the FITs/FIPs.

As mentioned above, the total period of support for all renewable sources in Poland is limited to 15 years and includes the time of support under any system (green certificates, auctions, FIT/FIP). Due to the fact that the first support scheme (the green certificate system) was adopted in 2005, all existing plants which enrolled in this scheme that year have lost the right to any kind of support as of 2020. The number of such plants is 400 and their total installed capacity amounts to 127 MW. These plants now face serious financial challenges as the wholesale market prices for electricity are not sufficient to cover their generation costs (ranging from approximately PLN 194 (USD 53) to PLN 245 (USD 67) per MWh in the two previous years). The reduction of revenue together with the high costs of electricity generation have increased the risk of these plants ceasing operation. The Polish SHP sector has requested remedial measures, including an extension of the support period for small and micro-hydropower plants. At the moment of writing of this chapter, a draft law was in the works to extend the support period for SHP plants and biogas installations by two years.[34,35]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Poland is among the countries with low average water availability, low rate of water reservoir capacity and increasing problems with water uptake. These problems have been intensifying due to the effects of climate change and are already affecting the hydropower sector in the country.[4,36] Future impacts largely depend on the progress of climate change over the course of the century. A recent study modelled the hydrological conditions in the Lusatian Neisse River basin and their impact on electricity generation of German and Polish SHP plants located in the basin based on two different climate change scenarios (RCP2.6 and RCP8.5, representing moderate and extreme scenarios for solar radiation levels in 2100, respectively). It concluded that in terms of hydropower, both positive and negative outcomes are possible. Under the RCP2.6 scenario, generation could increase by as much as 6–7 per cent by 2100 relative to the period 2015–2020, while under the RCP8.5 scenario, generation was projected to decrease by 31–34 per cent by 2100 relative to 2015–2020 across most surveyed plants. The study warns of significant energy problems in the basin if the extreme climate scenario is realized.[37]

BARRIES AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

In general, SHP development in Poland faces a large number of obstacles, including:

- Long-lasting, complicated and costly administrative procedures (especially in terms of environmental assessment) and lack of simplified procedures for small and micro-hydropower;
- High investment and operational costs of projects, resulting from the obligation of SHP plant operators to provide services connected to water regulation and maintenance of state-owned water facilities, channels and riverbeds as well as to continuously adapt throughout the whole lifespan of the plant to increasingly rigorous environmental requirements (e.g., building fish passes and fish barriers, increasing residual flow);
- Adoption of water pricing for hydropower since 2018 and the increase in fees paid for using damming structures and inundated lands owned by the state;
- Lack of effective and uniform regulations allowing the utilization of existing weirs for hydropower purposes;
- Support period of 15 years not adjusted to the lifespan of SHP projects (typically 60–70 years) and financial difficulties with the upkeep of SHP plants after the expiry of the support period;
- Lack of spatial development plans that include SHP;
- Lack of predictability of legal regulations and dependency on the regulated renewable energy market, which is especially difficult for small investors;
- Climate risk to hydropower in Poland under pessimistic climate change scenarios.

Enabling factors for SHP development in Poland include the following:

- The FIT/FIP scheme now offers support for newly constructed SHP plants;
- Very large number (over 8,500) of previously constructed water facilities across the country that could be refurbished or re-equipped as SHP plants;
- Possible increases in potential hydropower generation under optimistic climate change scenarios.

REFERENCES

1. Statistics Poland (2020). *Population by gender, feminization coefficient, population density*. Available at http://swaid.stat.gov.pl/EN/Demografia_dashboards/Raporty_predefiniowane/RAP_DBD_DEM_1.aspx (Accessed 27 May 2021).
2. Statistics Poland (2020). *Area and population in the territorial profile in 2020*. Available at: https://stat.gov.pl/en/topics/population/population/area-and-population-in-the-territorial-profile-in-2020,4,14.html (Accessed 27 May 2021).
3. PWN Encyclopedia (n.d.). *Poland. Natural conditions.* Available at https://encyklopedia.pwn.pl/haslo/Polska-Warunki-naturalne;4575152.html [in Polish] (Accessed 27 May 2021).

4. KLIMADA Project (n.d). *Global warming and its impact on Europe and Poland*. Available at: http://klimada.mos.gov.pl/en/climate-change-in-poland/ (Accessed 27 May 2021).
5. Polish Power System (PSE) (2020). *Statement of quantitative data on the functioning of the National Electricity System in 2020*. Available at https://www.pse.pl/dane-systemowe/funkcjonowanie-kse/raporty-roczne-z-funkcjonowania-kse-za-rok/raporty-za-rok-2020#t1_1 [in Polish] (Accessed 27 May 2021).
6. Energy Regulatory Office (URE) (2020). *National Report of the President of Energy Regulatory Office 2020*. Available at: https://www.ure.gov.pl/download/2/512/NR2020UREclean.pdf (Accessed 27 May 2021).
7. Energy Regulatory Office (URE) (2020). *Installed renewable energy capacity in Poland (as of 31 December 2020).* Available at: https://www.ure.gov.pl/pl/oze/potencjal-krajowy-oze/5753,Moc-zainstalowana-MW.html [in Polish] (Accessed 27 May 2021).
8. World Bank (n.d.). *Access to electricity (% of population) – Poland.* Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=PL (Accessed 28 May 2021).
9. Polish Power System (PSE) (2020). *Polish Power System. System in general (as of 31 December 2020).* Available at https://www.pse.pl/web/pse-eng/areas-of-activity/polish-power-system/system-in-general (Accessed 27 May 2021).
10. Center of Information on Energy Market (CIRE) (n.d.). *Information on current and planned constructions and extensions of electrical and thermal power stations in Poland*. Available at: https://rynek-energii-elektrycznej.cire.pl/st,33,335,tr,145,0,0,0,0,0,budowane-i-planowane-elektrownie.html [in Polish] (Accessed 28 May 2021).
11. Center of Information on Energy Market (CIRE) (n.d.). *Incredible increase of installed power in Polish photovoltaics. We are chasing Spain*. Available at: https://www.gramwzielone.pl/energia-sloneczna/104473/niesamowity-wzrost-mocy-w-polskiej-fotowoltaice-gonimy-hiszpanie (Accessed 28 May 2021).
12. European Small Hydropower Association (ESHA) (2010). *Guide on How to Develop a Small Hydro-power Plant – Polish edition*. Available at http://trmew.pl/fileadmin/user_upload/current_version/trmew.pl/strona_glowna/aktualnosci/2021/podrecznik_ESHA/Jak_zbudowac_mala_elektrownie_wodna_Przewodnik_inwestora_ESHA2010.pdf [in Polish] (Accessed 28 May 2021).
13. Energy Regulatory Office (URE) (2021). *Renewable energy installations as of 31 December 2020*. Available at: https://www.ure.gov.pl/pl/oze/potencjal-krajowy-oze/8108,Instalacje-odnawialnych-zrodel-energii-wg-stanu-na-dzien-31-grudnia-2020-r.html (Accessed 28 May 2021).
14. European Small Hydropower Association (ESHA) (2016). *HYDI Database*. Polish Association for Small Hydropower Development (TRMEW) Archive.
15. 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.
16. Statistics Poland (2021). *Energy from renewable sources in 2020*. Available at https://stat.gov.pl/download/gfx/portalinformacyjny/pl/defaultaktualnosci/5485/3/15/1/energia_ze_zrodel_odnawialnych_w_2020_r.pdf [in Polish] (Accessed 6 July 2021).
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. Hoffmann, A. & Hoffmann, M. (1961). *Cadastre Of Technical Resources of Water Energy in Poland*.
20. Steller, J. (2005). *Hydropower in Poland and in the European Union. Opportunities and Barriers of Development.* National Forum on Renewable Energy Sources. Warsaw.
21. Polish Association for Small Hydropower Development (TRMEW) (n.d.). *Poland's Hydropower Potential*. Available at http://trmew.pl/index.php?id=91 [in Polish] (Accessed 28 May 2021).
22. Polish Association for Small Hydropower Development (TRMEW) (n.d.). Internal database.
23. RESTOR Hydro Map (2015). Available at http://hydropower.kamilpiwowarski.pl/app (Accessed 28 May 2021).
24. Rankin, J. (2019). *European Green Deal to press ahead despite Polish targets opt-out*. The Guardian. Available at https://www.theguardian.com/environment/2019/dec/13/european-green-deal-to-press-ahead-despite-polish-targets-opt-out (Accessed 28 May 2021).
25. Ministry of Economy (2009). *Energy Policy of Poland until 2030*. Adopted by the Council of Ministers on 10 November 2009. Available at https://wfosigw.wroclaw.pl/files/download_pl/773_polityka-energetyczna-polski-do-2030.pdf [in Polish] (Accessed 28 May 2021).
26. Ministry of Climate and Environment (2021). *New Draft of Energy Policy of Poland until 2040*. Ministry of Climate and Environment. Available at https://www.gov.pl/web/klimat/polityka-energetyczna-polski [in Polish] (Accessed 28 May 2021).
27. Sejm of the Republic of Poland (2015). *The Act from 20 February 2015 on Renewable Energy Sources. Dz.U. 2015 poz. 478 with later amendments.* Online System of Legal Acts (ISAP). Available at http://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=wdu20150000478 [in Polish] (Accessed 29 May 2021).
28. Malicka. E. (2020). *The Polish small hydropower association fights for rescuing electricity producers in small hydropower plants*. Center of Information on the Energy Market (CIRE). October 2020. Available at https://www.cire.pl/item,205583,8,0,0,0,0,0,stowarzyszenie-trmew-walczy-o-ratunek-dla-malych-elektrowni-wodnych.html [in Polish] (Accessed 29 May 2021).
29. European Small Hydropower Association (ESHA) (2015). *Small and micro hydropower restoration handbook. The all-Inclusive replicable model*. RESTOR Hydro. Available at http://trmew.pl/fileadmin/user_upload/current_version/

trmew.pl/strona_glowna/aktualnosci/2019/08/Podrecznik_MEW_Restor_Hydro.pdf [in Polish] (Accessed 29 May 2021).
30. Polish Association for Small Hydropower Development (TRMEW) (2020). Report to the Ministry of Climate and Environment (unpublished).
31. AVANTA Audit (2020). *Report on the financial consequences of the expiry of the support schemes for small hydropower plants with a capacity below 1 MW*.
32. Minister of Climate (2020). *Decree of the Minister of Climate of 24 April 2020 on the reference price of electricity from renewable energy sources in 2020 and terms for producers who won auctions in 2020. Dz. U. z 2020 r. poz. 798*. Online System of Legal Acts (ISAP). Available at https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20200000798 [in Polish] (Accessed 29 May 2021).
33. Energy Regulatory Office (URE) (n.d). *Announcements on the results of auctions*. Available at: https://ure.gov.pl/pl/oze/aukcje-oze/ogloszenia-i-wyniki-auk?page=0 [in Polish] (Accessed 29 May 2021).
34. Council of Ministers of the Republic of Poland (2020). *Draft Amendment to the RES Act No. UD 107*. Polish Legislation Center (RCL). Available at https://legislacja.rcl.gov.pl/projekt/12336702/katalog/12704360#12704360 [in Polish] (Accessed 29 May 2021).
35. Wawrzyniak, K. (ed.) (2020). *Local dimension of energy*. KlastER project. Available at: http://trmew.pl/fileadmin/user_upload/current_version/trmew.pl/strona_glowna/aktualnosci/2021/03/Raport_Lokalny_Wymiar_Energii_1.3.pdf [in Polish] (Accessed 30 May 2021).
36. Suchożebrski J. (2018). *Water resources management in Poland – 2018*. Global Compact Network Poland. Available at https://www.researchgate.net/profile/Jaroslaw-Suchozebrski-2/publication/330451499_Zasoby_wodne_Polski/links/5c40c267299bf12be3cf3c90/Zasoby-wodne-Polski.pdf [in Polish] (Accessed 14 July 2021).
37. Adynkiewicz-Piragas, M. & Miszuk, B. (2020). Risk analysis related to impact of climate change on water resources and hydropower production in the Lusatian Neisse River basin. *Sustainability, 12*(12), 5060. Available at https://www.mdpi.com/2071-1050/12/12/5060/pdf (Accessed 30 May 2021).

Romania

Bogdan Popa and Eliza-Isabela Tica, University Politehnica of Bucharest

KEY FACTS

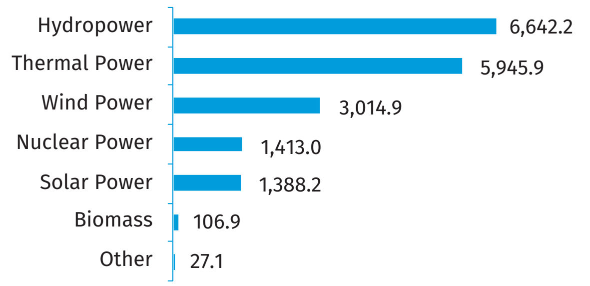
Population	19,186,000 (2021)[1]
Area	238,391 km^2[2]
Topography	The landscape of Romania is composed of nearly equal shares of mountains (31 per cent), hills (33 per cent) and plains (36 per cent). The landscape slopes downward from the Carpathian Mountains reaching more than 2,400 metres above sea level to just a few metres above sea level at the Danube Delta.[3]
Climate	Romania has a temperate continental climate with four seasons. The winters are cold and cloudy with frequent snow and fog, while the summers are sunny with frequent showers and thunderstorms. The average temperature ranges between -11 °C and 10 °C in the southern part of the country and between -9°C and 8.5 °C in the north. Maximum average temperatures during the summer are between 22 °C and 24 °C and between -5 °C and -3 °C in the winter.[4,5]
Climate Change	Observations indicate an increase in scorching heat intensity in Romania over the last several decades. The scorching heat index increased from 13 units between 1961 and 1990 to 28 units between 1981 and 2010, with the maximum length of heatwaves also being on the rise. Projected climate change impacts include a rise in average monthly temperatures of up to 3 °C and a sharp (8–9 per cent) decrease in precipitation during the summer months between 2021 and 2051, relative to the 1961–1990 reference period.[6]
Rain Pattern	Precipitation in Romania follows a decreasing pattern from west to east and from higher to lower elevations. Some mountainous areas receive more than 1,010 mm of precipitation each year. Annual precipitation averages approximately 635 mm in central Transylvania, 521 mm at Iaşi in western Romania and only 381 mm at Constanţa on the Black Sea.[7]
Hydrology	The most important river of Romania is the Danube. Its lower course forms a delta that covers much of the north-eastern part of the Dobruja region. Most of the major rivers in the country are part of the Danube system, including the Mures, the Somes, the Olt, the Prut, and the Siret. Romania has many small, freshwater mountain lakes, as well as large saline and freshwater lagoons on the coast of the Black Sea. The largest of these is Lake Razelm.[4]

ELECTRICITY SECTOR OVERVIEW

The installed capacity of Romania as of March 2022 was 18,538.2 MW, decreasing from 20,582.0 MW in 2020. Hydropower provided 6,642.2 MW (36 per cent) of this total, thermal power provided 5,945.9 MW (32 per cent), wind power provided 3,014.9 MW (16 per cent), nuclear power provided 1,413.0 MW (8 per cent), solar power provided 1,388.2 MW (8 per cent) and biomass and other sources provided 134.0 MW (less than 1 per cent) (Figure 1).[8,9]

The decrease in installed capacity since 2020 was a result of the continuation of measures taken by the National Energy Regulatory Authority (ANRE) during 2020 and 2021 to withdraw or amend some licences issued to producers with an installed capacity larger than their practically available capacity, based on their declarations of availability, to better reflect the actual situation in the power sector. Unavailable power units were then removed from the inventory of installed capacity, resulting in a significant reduction of the nationwide installed capacity total.

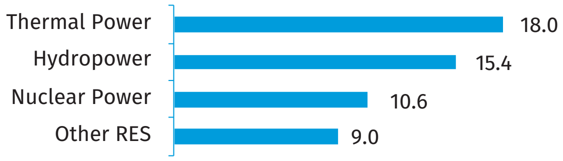
Figure 1. **Installed Electricity Capacity by Source in Romania in 2022 (MW)**



Source: ANRE[8]

Total generation of electricity in Romania in 2020 reached 53.0 TWh, with 18.0 TWh (34 per cent) of the total provided by thermal power, 15.4 TWh (29 per cent) provided by hydropower, 10.6 TWh (20 per cent) provided by nuclear power and the remaining 9.0 TWh (17 per cent) provided by other renewable energy sources (RES) (Figure 2). The share of electricity generation in 2020 from RES, including hydropower, was 46 per cent.[9]

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



Source: Transelectrica[9]

Exports of electricity in 2020 amounted to 4.0 TWh, while imports were 6.8 TWh, with domestic consumption reaching 55.8 TWh.[9] Electricity access in Romania as of 2019 was 100 per cent.[10]

The capacities of the national grid of Romania have been challenged by the rapid development of wind and solar power concentrated in the south-eastern and eastern areas of the country, particularly in the Dobruja region. Consequently, grid access for new RES power plants has been increasingly restricted.[4]

Electricity distribution is organized according to several zones with a private electricity provider responsible for each zone: Banat (Enel), Transilvania Nord (Electrica), Transilvania Sud (Electrica), Oltenia (CEZ), Muntenia Sud (Enel), Muntenia Nord (Electrica), Moldova (E.On) and Dobruja (Enel). The Government regulates transmission and distribution tariffs for every region. Electricity tariffs for end users are differentiated based on voltage level rather than by sector or consumer category. The tariffs are updated by ANRE on an annual basis.[4,11] Regional generic electricity tariffs for July–December 2020 are displayed in Table 1.

Table 1. **Regional Generic Electricity Tariffs for July–December 2020**

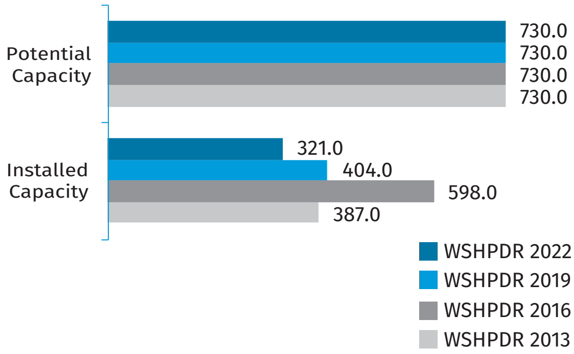
Region	*Price (RON/kWh (USD/kWh))*	
	Medium voltage	*Low voltage*
Banat	0.322 (0.071)	0.430 (0.095)
Dobrogea	0.302 (0.066)	0.433 (0.095)
Muntenia Sud	0.289 (0.063)	0.402 (0.088)
Moldova	0.318 (0.070)	0.448 (0.099)
Muntenia Nord	0.328 (0.072)	0.451 (0.099)
Transilvania Nord	0.343 (0.075)	0.447 (0.098)
Transilvania Sud	0.335 (0.074)	0.440 (0.097)
Oltenia	0.352 (0.077)	0.473 (0.104)

Source: ANRE[11]

SMALL HYDROPOWER SECTOR OVERVIEW

The definition of small hydropower (SHP) in Romania includes hydropower plants with an installed capacity up to 10 MW. In 2020, the total installed capacity of SHP in Romania accredited by ANRE was 321 MW provided by 103 plants, including 18 recently refurbished plants with a total capacity of 55 MW.[11] The potential capacity of SHP is estimated at 730 MW, indicating that approximately 44 per cent has been developed. Relative to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity of SHP in the country has decreased by nearly 21 per cent due to a reassessment of actual installed capacities of operating plants by ANRE, while estimates of potential capacity have remained the same (Figure 3).[4]

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



Source: *WSHPDR 2019*,[4] ANRE,[11] *WSHPDR 2013*,[12] *WSHPDR 2016*[13]

The biggest hydropower potential in Romania is concentrated in the mountain areas, especially within the Carpathian Mountains Arch in the Transylvania region. The hydrographic basins most suitable for SHP development include the Mures, Arges, Buzau, Jiu, Crisurile, Nera and Siret River Basins.[4] A partial list of existing SHP plants in Romania is provided in Table 2.

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

Name	*Location*	*Capacity (MW)*	*Head (m)*	*Operator*	*Launch year*
Măneciu II	Măneciu	0.075	43.4	TOTAL TRANS SRL	2021
Măneciu I	Măneciu	0.269	N/A	TOTAL TRANS SRL	2021
Baraj Someș	Cuzdrioara	1.890	N/A	MHPP ENERGY SOMES SRL	2017
Valea Mare	Bistrița Năsăud	0.990	N/A	MHC Valea Mare SRL	2016
Secuș	Mureș county	1.123	N/A	BETONMIX SRL	2016
MHC C1 (Canciu)	Alba county	2.310	N/A	SC ENERGIS ROTT SRL	2016

Name	Location	Capacity (MW)	Head (m)	Operator	Launch year
Viromet	Brașov country	0.395	N/A	VIROMET S.A.	2015
Zagra 1	Sat Suplai	0.402	N/A	ZAGRA HIDRO SA	2014
Zagra 2	Sat Suplai	0.331	N/A	ZAGRA HIDRO SA	2014
MHC C2 (Boșorogu)	Alba county	1.650	N/A	S.C. ROTT HAUS CONSULTING S.R.L.	2014
Răcătău	Măguri-Răcătau-Mărișel	1.600	123.6	RENOVATIO TRADING SRL	2013
Viștea	Brașov county	1.188	N/A	Vistea Hidro-electrica SRL	2013
Viștișoara	Brașov country	2.400	N/A	HIDRO CLEAR FAGARAS SRL	2013
Valea Ming-hetului Suciu	Groșii Țibleșului	0.995	N/A	HYDROTECH ELECTRIC SRL	2013
Valea Lui Vlad	Groșii Țibleșului	1.162	N/A	SC HIDRO-ELECTRICA DEL VALEA LUI VLAD SRL	2013
Valea Stan-ciului	Mărgău	0.959	N/A	BETA ENERGIE REGENERABILA srl	2012
Valea Neagra 1	Firiza	1.760	N/A	S.C. IDROSEI S.A	2012
Valea Neagra 2	Firiza	0.800	N/A	S.C. IDROSEI S.A	2012
Vlahita	Harghita county	0.956	N/A	H2O ENERGY SA	2011
Zetea	Harghita county	3.960	N/A	UZINSIDER GENERAL CON-TRACTOR S.A.	2007

Source: Transelectrica[14]

RENEWABLE ENERGY POLICY

The promotion scheme for RES project development was established by Law 220 from 2008. Initially, the promotion scheme issued one Green Certificate (GC) for each MWh generated from RES, including SHP, wind power, solar power, biomass, biogas and geothermal power, for a 15-year period. In 2010, the promotion scheme was changed, granting different numbers of GCs for each RES as follows: 3 GCs for new SHP plants and 2 GCs for refurbished SHP plants for a 10-year period, 2 GCs for wind power plants for the first 5 years and then 1 GC for the following 10 years, 6 GCs for solar power plants and 4 GCs for biomass and biogas plants. This change temporarily made Romania one of the most attractive countries in the European Union for RES investments.[4]

In 2013, the Government of Romania issued Emergency Ordinance No. 57/2013, which established modifications to the RES promotion scheme defined by the Law 220/2008.[15]

Legal modifications, which affected the number of GCs and limitations in annual quotas, caused a large number of GCs to no longer be traded and resulted in RES producers being unable to transform this form of incentives into cash flow. The producers kept their untraded GCs, which caused the price of GCs on the market to drop from the maximum value established by the legislation of EUR 55 (USD 63) to the minimum value of EUR 30 (USD 34). Consequently, it has been difficult to attract financial support for green energy projects.

The Law 220/2008 was additionally modified with GD 994/2013 and several GCs for RES projects were delayed until 2017, 2018 and 2020 respectively. This decision was taken to reduce the impact on end-user electricity tariffs from the incentives granted to RES. However, the RES promotion scheme established by the Law 220/2008 ended in 2016 and subsequently only those RES projects that were commissioned before the end of 2016 were able to benefit from of the GC scheme, with the last issued GCs to run out in 2031. As a result, no large-scale RES projects have been developed or built since 2017.[4]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The key issues hampering the development of SHP in Romania are as follows:

- No current legislation for the promotion of RES with GCs or other financial incentives, discouraging investors;
- Complex procedure for obtaining a water use permit and securing a location for SHP plant development. Obtaining water use rights requires the investor to first rent the necessary surface of the minor riverbed after a public tender and only then apply for a water use permit;
- Excessive cost of water for power generation making low-head SHP projects economically unfeasible;
- Opposition from environmental groups caused by a recent increase in SHP projects in upstream mountain areas;
- Lack of up-to-date estimates of countrywide SHP potential;
- Legislation significantly complicating access for RES projects to the national grid.

The primary enabler for SHP development in Romania is the significant undeveloped potential SHP capacity remaining in the country.

REFERENCES

1. National Institute of Statistics (2021). *Comunicat de presa*. Available at https://insse.ro/cms/sites/default/files/com_presa/com_pdf/poprez_ian2021r.pdf [in Romanian] (Accessed 28 March 2022).

2. Nations Online (n.d.). *Romania*. Available at https://www.nationsonline.org/oneworld/romania.htm (Accessed 28 March 2022).
3. Bachman, R.D. (ed.) (1989). *Romania: A Country Study. Topography*. Available at http://countrystudies.us/romania/33.htm (Accessed 28 March 2022).
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.
5. National Administration of Meteorology (2008). *Romanian Climate*. Romanian Academy Publisher, Bucharest.
6. Ministry of Environment (2017). *Romania's 7th National Communication under the United Nations Framework Convention on Climate Change*. Available at https://unfccc.int/sites/default/files/resource/0587134_Romania-NC7-1-NC7_ROMANIA.pdf (Accessed 28 March 2022).
7. Bachman, R.D. (ed.) (1989). *Romania: A Country Study. Climate*. Available at http://countrystudies.us/romania/34.htm (Accessed 28 March 2022).
8. National Energy Regulatory Authority (ANRE) (2022). *Puterea instalata in capacitatiile de productie energie electrica*. Available at https://www.anre.ro/ro/energie-electrica/rapoarte/puterea-instalata-in-capacitatiile-de-productie-energie-electrica [in Romanian] (Accessed 28 March 2022).
9. Transelectrica (2020). *Raport Anual 2020.* Available at https://www.transelectrica.ro/documents/10179/11684857/Raport+Anual+2020.pdf/e3725341-5dcd-4ac5-bcc2-37eb-817f17eb [in Romanian] (Accessed 28 March 2022).
10. World Bank (n.d.). *Electricity access (% of population) – Romania*. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=RO (Accessed 28 March 2022).
11. National Energy Regulatory Authority (ANRE) (2022). *Raport Anual 2020*. Available at https://www.anre.ro/download.php?f=fqh8haU%3D&t=vdeyut7dlcecrLbbvbY%3D [in Romanian] (Accessed 28 March 2022).
12. 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.
13. 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.
14. Transelectrica (2022). *Lista unitatilor de productie*. Available at https://www.transelectrica.ro/documents/10179/9800669/LISTA+UNITATILOR+OEA/f5086bc9-a7f8-465c-b612-ce1dbed0a15d [in Romanian] (Accessed 28 March 2022).
15. Blajin, C. (2019). *Promotion in Romania.* RES Legal. Available at http://www.res-legal.eu/search-by-country/romania/tools-list/c/romania/s/res-e/t/promotion/sum/184/lpid/183/ (Accessed 31 May 2022).

Russian Federation

Galina Livingstone, Livingstone Environmental Ltd.

KEY FACTS

Population	146,493,388 (2020).[1]
Area	17,125,191 km^2 [2]
Topography	The topography of Russia includes broad plains with low hills found west of the Urals, vast coniferous forest and tundra in Siberia and uplands and mountains along the southern border regions. The highest point in Russia is Mount Elbrus (5,642 metres), which is also the highest point in Europe. The lowest locations are found near the shores of the Caspian Sea.[3]
Climate	The climate of Russia varies considerably owing to its extensive territory. The climate is humid continental climate in much of the European Plain area in the western part of Russia, subarctic in the Siberia region to the centre-north and tundra in the polar north. Winters vary from cool along the Black Sea coast to frigid in Siberia; summers vary from warm in the steppes to cool along the Arctic coast. The average temperature in January is -26.7 °C, varying from 0 °C in the North Caucasus to -50 °C in the Republic of Yakutia. The average temperature in July is 14.8 °C, but it can be as low as 1 °C in the northern coastal areas of Siberia and reach 25 °C in the Caspian region.[4]
Climate Change	Being one of the largest producers of fossil fuels in the world, Russia accounts for nearly 5 per cent of global CO_2 emissions. The recent increase in the mean annual temperature is approximately 2.5 times higher in Russia than the worldwide average. In the period 1976–2016, temperatures on average increased by 0.45 °C every 10 years, with the greatest rates of increase (0.72–0.77 °C) observed in Siberia in the spring and fall. This temperature increase is associated with serious environmental hazards, such as the thawing of permafrost, increase in the frequency of wildfires, peatland fires, flash floods, coastal flooding and increased soil erosion.[5]
Rain Pattern	The majority of the territory of Russia has little exposure to ocean influences. Most of the country receives low to moderate amounts of precipitation. The average annual precipitation in the country is 423 mm. Precipitation is highest in July (64.3 mm) and lowest in February (15.8 mm).[4] Most precipitation falls in the north-west, with amounts decreasing from north-west to south-east across European Russia.
Hydrology	There are over 2.5 million rivers, more than 2.7 million lakes and hundreds of thousands of wetlands on the territory of the Russian Federation. The total volume of static freshwater resources is estimated at 88,900 km^3, with a significant proportion represented by underground water. Russia possesses approximately 20 per cent of the world's freshwater resources, but this water is rather unevenly distributed within the territory. Approximately 90 per cent of the river flow volume in the country belongs to the Arctic basin. Thus, the central and southern regions of European Russia, where 80 per cent of the country's population and industry are concentrated, have only 10 per cent of freshwater resources.[6]

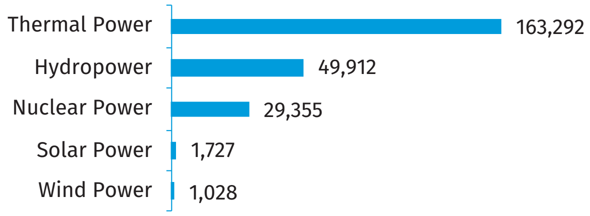
ELECTRICITY SECTOR OVERVIEW

Russia is one of the top producers and consumers of electric power in the world.[7] The Russian Federation Energy Strategy for the period up to 2035 assumes further increases of electric power consumption, particularly in the regions with accelerating economic development including the Russian Far East, the Russian North, Siberia and the Caspian region.[8] Russia has rich gas, oil and coal reserves, therefore, thermal power plants contribute the largest share of electricity generation, but nuclear power and hydropower also provide a significant contribution.

The United Energy System (UES) Group of Russia provides most of the country's electricity and exports power to neighbouring countries over the UES network. UES is the largest centrally controlled electric power system in the world, composed of 880 power plants of over 5 MW.[10] The UES of Russia works in parallel with the UES of Azerbaijan, Belarus, Georgia, Kazakhstan, Latvia, Lithuania, Mongolia, Ukraine and Estonia on the basis of bilateral agreements.[9,10] The Russian Federation is working together with other members of the Eurasian Economic Union towards the establishment of a joint energy market and transition to a coordinated energy policy.

As of 1 January 2021, the total installed capacity of UES power plants was 245,313 MW. Thermal power plants made up nearly 67 per cent of this total, hydropower 20 per cent, nuclear power 12 per cent and wind and solar power combined approximately 1 per cent (Figure 1).[11]

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

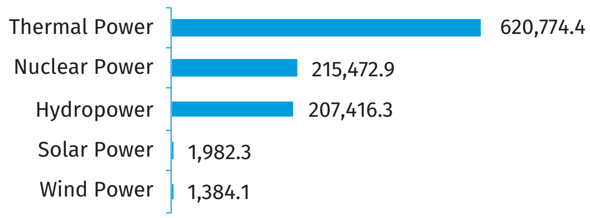


Source: UES System Operator[11]

Hydropower plants are one of the key components of the UES, providing over 90 per cent of the regulated power capacity reserve.[11] The federal hydropower generation company, PJSC RusHydro, owns the majority of the hydropower plants in the country. As of 31 December 2020, the Government of the Russian Federation owned approximately 62 per cent of the RusHydro share capital.[12]

Total net electricity generation in 2020 was 1,047 TWh, of which thermal power including industrial power plants provided 59 per cent, nuclear power plants 21 per cent, hydropower plants 20 per cent, and solar and wind power plants combined less than 1 per cent (Figure 2).[9]

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



Source: UES System Operator[9]

Total electricity consumption in 2020 was 1,033 TWh. Relative to 2019, electricity generation decreased by 3 per cent, while consumption decreased by approximately 2 per cent.[9] The decrease in generation and consumption was partially a result of cuts in oil output as part of the OPEC+ (Organization of the Petroleum Exporting Countries and allies) agreement of 2020, reducing power demand by oil pipelines, and partially due to an overall decrease in economic activity caused by COVID-19. The latter is expected to continue to impact electricity demand and production in Russia beyond 2021.

The power distribution is performed over more than 10,700 electric transmission lines of 110–1,150 kV and controlled by 7 major regional Joint Energy Systems spread across the 85 federal subjects of Russia. PJSC Rosseti is the main operator of energy grids in Russia. The company maintains 2.37 million kilometres of power transmission lines and 517,000 substations with transformer capacity of more than 802 GW (2019). The controlling shareholder of the company is the Federal Agency for State Property Management of the Russian Federation, which owns 88 per cent of the share capital.[13] The UES Federal Grid Company (FGC UES), a subsidiary of PJSC Rosseti, acts as the operator and manager of the Unified National Electric Grid (UNEG) of Russia, including the high-voltage transmission lines.[14] The FGC UES is responsible for transmission of power over the electrical grids and provision of technological connections to the electrical grid for electricity consumers, generating power plants and the transmission facilities of other owners. These activities are both natural monopolies and therefore regulated by the state.

The electrification rate in Russia is 100 per cent.[15] The country was ranked seventh in the world by availability of electricity by the World Bank in 2019 and scored eighth out of eight in power supply reliability and transparency of tariffs.[16] However, several structural problems with providing energy to consumers still exist. For example, many settlements located in sparsely populated areas such as the Russian North, Siberia and Far East are not connected to UNEG.[17] These regions rely on the local power generation facilities and imported fuel for power plants. Yakutia is a typical example of such a region; the local company, PJSC SakhaEnergo, supplies electric power to an area of approximately 2.4 million km^2 occupied by a population of about 105,000, mostly by means of 136 autonomous diesel power plants.[18] As a consequence of the collapse of the Soviet Union energy management system, some minor grids in remote areas have no registered owner at all; the Government is currently discussing returning these to state ownership.

There are several regions in the country classified by the Russian Federation Energy Ministry as being at high risk of electric power supply interruption, including Dagestan, Irkutsk oblast' and others. These risks arise mostly due to an insufficient local power infrastructure. The Energy Ministry is implementing plans for mitigating such risks.[19] As such, modernization of existing generation capacities and implementation of new generating technologies, including an accelerated development of renewable energy capacities, are key strategic objectives for the Russian electricity industry. Federal Law on the Electric Power Energy Industry No. 196-FZ was updated in 2016 by the inclusion of enhanced requirements for the reliability and safety of the electric power facilities and distribution systems.[20] Russian electricity consumption is expected to increase by 1.1 per cent per year on average in 2020–2026.[21]

The Russian electricity market consists of wholesale and retail markets. Liberalization reform plans for the Russian electricity market assume a future transition to a fully non-regulated electric power market. However, liberalization currently applies only to the wholesale sector, where most of the electricity is now traded at non-regulated market prices. Public tariffs are likely to remain state-regulated for the foreseeable future. For electricity price control, the country is split into two market price zones (European Russia–Ural zone and Siberia) as well as the non-price zones (Kaliningrad oblast', Far East, Arkhangelsk oblast' and the Komi Republic) (Figure 3). The reason for such division is a limited capacity of interconnection between these zones within UNEG and different structures of the production capacity, e.g., predominance of relatively cheap hydropower in Siberia.[22] The State regulates electricity prices in the non-price zones because electricity supply is totally isolated from UES in those areas.

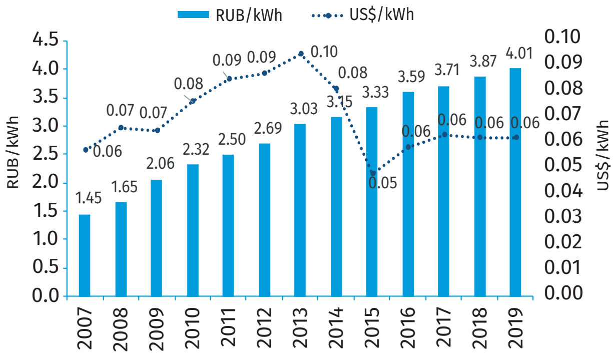
Figure 3. **Electricity Market Price Zones in the Russian Federation**

Source: Association NP Market Council (2020)[23]

The responsibility for setting regulated tariffs for electricity and capacity supplied to the residential consumers as well as tariffs for the electricity supply in the non-price zones lies with the Federal Anti-Monopoly Service (FAS).[24] FAS also regulates the tariffs for renewable energy, e.g., in the case of electric power purchased for compensating the grid losses.

The average electricity tariff for the end consumer in the retail market steadily increased over the past years. Average tariffs for the period 2007–2019 are displayed in Figure 4.

Figure 4. **Average Electricity Tariff for Residential Consumers in Russia in 2007–2019 (USD/kWh)**



Source: Russian Federation Federal State Statistics Service[25]

Note: The decrease in USD/kWh tariffs between 2013 and 2015 reflects fluctuations in the USD/RUB exchange rate.

SMALL HYDROPOWER SECTOR OVERVIEW

The current regulatory definition of small hydropower (SHP) in Russia is hydropower plants with an installed capacity of up to 30 MW with a turbine wheel diameter of up to 3 metres.[22,26] The current chapter primarily considers data on SHP plants with an installed capacity up to 10 MW, but information on SHP up to 30 MW is also referenced. Additionally, it must be noted that strategic planning documents and state support schemes in Russia classify hydropower plants into two major groups: up to 25 MW and over 25 MW.[8,21] However, the 25 MW threshold is not the regulatory SHP definition, but rather a definition used for strategic planning purposes and promotion of renewable energy.

As of 2021, the installed capacity of SHP up to 10 MW was 168.4 MW and of SHP up to 30 MW it was 852.9 MW. The technically feasible potential for SHP up to 30 MW is estimated to be 825,844.6 MW, indicating that only approximately 0.1 per cent has been developed.[27,28,29,30,31,32,33]

The number of SHP plants operating in Russia published in Russian sources varies from 60–70 to 200–300, with the higher values found in the earlier reports. To clarify this discrepancy, an array of information about SHP plants in Russia was summarized in the *World Small Hydropower Development Report (WSHPDR) 2019*, concluding that the actual number of operational SHP plants with installed capacity below 10 MW was just over a hundred.[34] For the current edition, the overview of SHP plants has been updated using data utilized in the *WSHPDR 2019* and various recent publications (Table 1). Most of the currently operating SHP plants are located in the Republic of Karelia and the North Caucasus region. The total number of operating SHP plants with installed capacity up to 30 MW has decreased from 141 (*WSHPDR 2019*) to 118 due to the identification of SHP plants taken out of operation.

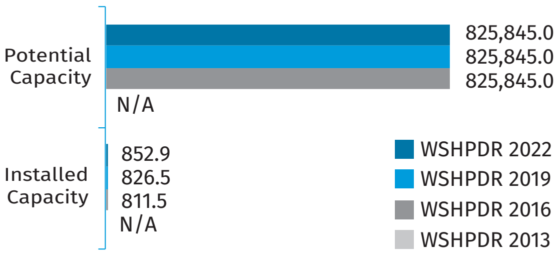
Table 1. **Installed and Potential Small Hydropower Capacity in Russia by Region**

	Federal District	Estimated potential capacity for SHP <30 MW (MW)			SHP <10 MW			SHP 10–30 MW			Total SHP <30 MW		
		Theoretically available	Technically feasible	Economically feasible	No. of SHP plants	Total installed capacity (MW)	% Technically feasible capacity <30 MW	No. of SHP plants	Total installed capacity (MW)	% Technically feasible capacity <30 MW	No. of SHP plants	Total installed capacity (MW)	% Technically feasible capacity <30 MW
1	North-Western	121,222.2	33,377.8	19,755.6	18	27.9	0.1	11	267.3	0.8	29	295.2	0.9
2	Central	18,688.9	6,466.7	3,488.9	19	30.1	0.5	2	57.8	0.9	21	87.9	1.4
3	Southern	100,444.4	30,666.7	17,111.1	5	11.6	0	1	21.6	0.1	6	33.2	0.1
4	North Caucasus	35,111.1	10,666.7	5,555.6	24	70.2	0.7	11	215.1	2	35	285.2	2.7
5	Volga	300,000.0	93,555.6	51,400.0	10	6.6	0	4	79.6	0.1	14	86.2	0.1
6	Ural	77,777.8	25,333.3	14,000.0	2	9.4	0	0	0	0	2	9.4	0
7	Siberian	966,800.0	301,777.8	166,222.2	5	7.1	0	0	0	0	5	7.1	0
8	Far Eastern	1,003,777.8	324,000.0	178,000.0	4	5.6	0	2	43.2	0	6	48.8	0
	Total	**2,623,822.2**	**825,844.6**	**455,533.4**	**87**	**168.5**	**0.0**	**31**	**684.6**	**0.1**	**118**	**853.0**	**0.1**

Source: Nefedova, L.,[27] Kiselyova, S.,[28] MSU and JIHT,[29] Hydropower Museum,[30] MNTO INSET,[31] RusHydro,[32] Nord Hydro,[33] *WSHPDR 2019*[34]

Changes in SHP installed and potential capacity relative to the *WSHPDR 2019* are displayed in Figure 5. A decrease in SHP capacity of up to 10 MW is partially accounted for by the decommissioning and temporary suspension of operations in a number of plants (Figure 6). Conversely, the overall increase in SHP installed capacity up to 30 MW is a result of the commissioning of additional SHP plants above 10 MW in capacity, as SHP plants with capacity between 10 MW and 30 MW are preferred for economic reasons. The figures cited in the current chapter also reflect more accurate data becoming available.

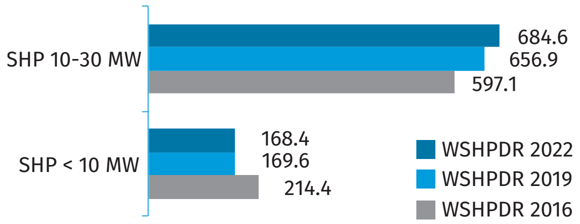
Figure 5. **Small Hydropower Capacities in the WSHPDR 2013/2016/2019/2022 in Russia (MW)**



Source: Nefedova, L.,[27] Kiselyova, S.,[28] MSU & JIHT,[29] Hydropower Museum,[30] MNTO INSET,[31] RusHydro,[32] Nord Hydro,[33] *WSHPDR 2019*,[34] *WSHPDR 2013*,[35] *WSHPDR 2016*[36]

Note: Data for SHP up to 30 MW.

Figure 6. **Small Hydropower Installed Capacities in the WSHPDR 2016/2019/2022 in Russia (MW)**



Source: Nefedova, L.,[27] Kiselyova, S.,[28] MSU & JIHT,[29] Hydropower Museum,[30] MNTO INSET,[31] RusHydro,[32] Nord Hydro,[33] *WSHPDR 2019*,[34] *WSHPDR 2016*[36]

In the Russian Federation, small rivers are defined as rivers less than 100 kilometres-long with a watershed area less than 2,000 km^2 and located within a single geographical zone.[37] Small rivers are prevalent in the hydrographic network of Russia: the share of small rivers shorter than 100 kilometres in the total length of the hydrographical network is 95 per cent, while their total flow constitutes an average of approximately 50 per cent of the total flow of all rivers in Russia.[38] The technically feasible generation potential of the small rivers in Russia is estimated at approximately 372 GWh per year.[39]

SHP plants in Russia have a long history. The first hydropower plant in the country, with an installed capacity of 0.18 MW, was constructed in the Altai region in 1882 for powering water pumps at the Zyryanovsky mine. Another unique example, the Porogy SHP plant of 1.45 MW, was constructed in the Chelyabinsk region in 1910 and remained operational until 2017.[40] Numerous SHP plants were constructed in the 1930s, but many were destroyed during the Second World

War. The SHP energy sector experienced a quick revival in the post-war years, with over 6,600 SHP plants in operation at the time.[41] Later, the Soviet energy policy was changed in favour of large hydropower plants. Thereafter, production of SHP equipment was closed and most SHP plants were taken out of operation and consequently abandoned. Recent surveys suggest that restoration of some of these SHP plants can be economically feasible.[42] The SHP sector in Russia is currently in a stage of revival and many plants have been built or refurbished in recent years. A partial list of recently commissioned and refurbished SHP plants is provided in Table 2.

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

Name	*Location*	*Capacity (MW)*	*Head*	*Plant type*	*Operator*	*Launch year*
Verhnebalkarskaya	Cherek Balkarskiy	10.00	125.0	Run-of-river	AO RusHydro	2020
Ust-Dzhegutinskaya	Kuban River	5.60	31.0	Reservoir	AO RusHydro	2020
Barsuchkovskaya	Barsuchkovskiy discharge canal	5.25	12.7	Reservoir	PAO RusHydro	2020
Maikopskaya Malaya GES	Belaya	0.40	N/A	Reservoir	OAO Adygenergostroy	1999/ 2020
Malaya Krasnopolyanskaya	Beshenka	1.50	230.0	Run-of-river	OOO Lukoil-ecoenergo	1947/ 2005/ 2020
SHP on Toolailyg river	Mouth of Barlyk river	0.05	N/A	Run-of-river	? (Community SHP)	2019
Bol'shoi Zelenchuk	Bolshoi Zelenchuk	1.26	9.0	Reservoir	AO RusHydro	2018
Uchkulanskaya	Uchkulan river	1.00	N/A	Run-of-river	ZAO Foton	1937/ 1987/ 2018
Enashiminskaya	Enashimo	5.00	59.5	Run-of-river	OOO Enashimskaya GES (AO Yuzhuralzoloto grupps companiy)	1961/ 2016
Kokadoiskaya	Argun river	1.30	N/A	Reservoir	GUP Chechenskaya Generiruyushchaya Kompaniya	2015
Lykovskaya	Zusha river	0.76	N/A	Reservoir	OOO Lykovskaya GES	1953/ 2015
Kalliokoski	Tohmajoki river	0.98	9.3	Reservoir	AO Nord Hydro	2014
Tomskaya	Cleaned wastewater discharge duct	1.00	N/A	Run-of-river	OOO Tomskaya generiruyuschaya kompanya	2014
Novokarachayevskaya	Kuban' river	1.26	N/A	Reservoir	ZAO Foton	2013
Ryymakoski	Tohmajoki river	0.63	9.2	Reservoir	AO Nord Hydro	1937/ 2013
Ulyanovskaya MGES-2	Ulyanovskiy purified wastewater discharge duct	0.32	35.0	Run-of-river	MUP Ulyanovskvodokanal	2011
Mukholskaya	Cherek Balkarskiy	0.90	28.5	Reservoir	AO RusHydro	1962/ 2011
Tokmovskaya	Moksha river	0.32	6.0	Reservoir	FBGU Mordovmeliovodkhoz	2010
Eshkakonskaya	Eshkakon	0.60	N/A	Reservoir	OOO Nizhegorodskiy Institute of Applied Technologies	2009
Fasnal'skaya	Songutidon	6.40	127.0	Run-of-river	OAO Turboholod	2009

Source: Nefedova, L.,[27] Kiselyova, S.,[28] MSU & JIHT,[29] Hydropower Museum,[30] MNTO INSET,[31] RusHydro,[32] Nord Hydro,[33] NP Soviet Rynka,[43] Tsukanov, V.I.[44]

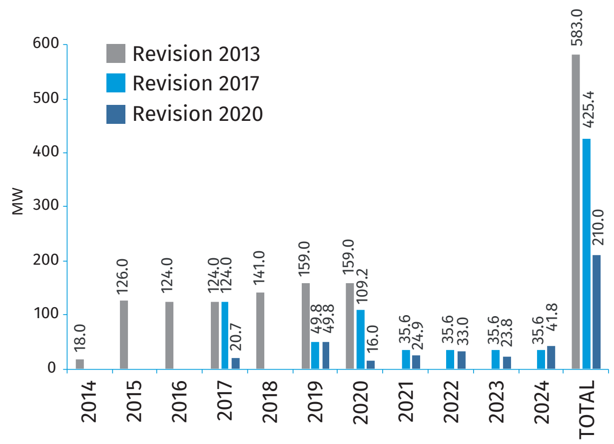
Russia possesses a variety of SHP technologies and produces equipment for SHP plants.[45,46,47,48] Two major SHP developers in the country are RusHydro and Nord Hydro. RusHydro's development programme for 2020–2026 includes the construction of a number of new SHP plants and the complete renovation of several existing ones, particularly in the North Caucasus and Southern regions.[49] Its targets also include the implementation of advanced technologies in SHP development, such as the use of new construction materials, the utilization of advanced electro-mechanical equipment for the remote monitoring of plant performance, the use of prefabricated container-type power generation units with an installed capacity below 5 MW, the installation of SHP plants of below 5 MW capacity on existing technological hydro-engineering systems and hybrid design of small power plants combining SHP with solar and/or wind generation facilities, among others.

Nord Hydro is currently planning the reconstruction of 37 SHP plants and the construction of 10 new SHP plants on company property. Furthermore, their strategic plan for the period up to 2025 includes the construction of SHP plants in 21 regions of Russia.[50] Nord Hydro is supported by the Russian Direct Investment Fund (RDIF) in developing SHP plants in the Republic of Karelia.[51,52] RDIF co-invested jointly with the Eurasian Development Bank (EDB) and the International Investment Bank (IIB) in the development of the Beloporozhskaya-1 and

Beloporozhskaya-2 SHP plants, with an installed capacity of 24.9 MW each.[53]

Russian Federation Government Resolution No. 861-r from 28 May 2013 established installed capacity targets for SHP development in 2013–2020.[54] These targets were later revised towards a noticeable reduction of the total planned capacity, while their implementation was extended to 2024 (Figure 7).[55,56] However, these SHP development targets had not been met as of 2021.

Figure 7. **Targets for Development of Small Hydropower in the Russian Federation in 2014–2024 (MW)**



Source: Government of the Russian Federation[54,55]

Note: The comparison is between the 2013, 2017 and 2020 revisions of the legislation on SHP targets; targets use the up to 25 MW definition of SHP.

The current state and corporate development plans and programmes in the Russian Federation include the construction and major renovation of approximately 40 SHP plants in 2020–2026. Examples of several ongoing projects are provided in Table 3.

Table 3. **List of Selected Ongoing Small Hydropower Projects in the Russian Federation**

Name	*Location*	*Capacity (MW)*	*Head*	*Plant type*	*Developer*	*Planned launch year*	*Development stage*
Dzaudzhikausskaya	Terek river	8.2	27	Run-of-river	PAO RusHydro	2025	Reconstruction
Sengileyevskaya	Nevinnomysskiy canal	18	45.5	Reservoir	PAO RusHydro	2025	Reconstruction
Psygansu	Psygansu river	3.7/19.1	284	Run-of-river	PAO RusHydro	2024	Design stage
Kubanskaya GAES	Bolshoy Stavropolskiy canal	19.4	24	Reservoir	PAO RusHydro	2025	Reconstruction
Gizeldonskaya	Gizeldon river	26.4	289	Run-of-river	PAO RusHydro	2025	Reconstruction

Source: Ministry of Energy,[21] RusHydro,[49] Nord Hydro[50]

There are thousands of potential SHP sites in Russia, therefore, it is practically impossible to list them all, given the scale of the country. Table 4 provides several examples of potential SHP sites. An extended list of selected potential SHP sites in Russia, as well as SHP projects under way in the country, is made available in the Global SHP database.

Table 4. **List of selected Potential Small Hydropower sites in the Russian Federation**

Name	*Location*	*Potential capacity (MW)*	*Head*	*Type of site*
Dargavskaya	Gizeldon River	2.8	130.0	New
Donguz-Orunkel	Baksan River	3.5	436.0	New
Yaglanporozhskaya	Chirka-Kem River	13.6	17.4	New
Kurminskaya	Karakoisu River	15.0	32.2	New
Zheleznoporogskaya	Chirka-Kem River	16.0	16.5	New

Source: Tsukanov, V.I.,[44] Government of the Republic of Karelia,[57] Government of the Republic of Chechnya,[58] Cleandex,[59] AO SO EES ODU Yuga[60] Kuvalkin et al.[61]

RENEWABLE ENERGY POLICY

The Government of the Russian Federation has recognized climate change as a major problem, ratifying the Paris Agreement in 2019, and has introduced plans for minimizing the climate change impacts.[62]

Renewable energy policy in Russia is set by the Government and considers accelerated development of renewable energy sources (RES) as an important factor of the economic modernization of the country.[56] The main focus of RES development in Russia are wind and solar power, with a comparatively minor role allocated to SHP.

The use of RES, including SHP, is considered in Russia as part of the broader concept of energy efficiency. In 2020, the Government approved an updated federal policy for increasing energy efficiency in the electric power industry through RES for the period up to 2035. The policy has set a target of 4.5 per cent for the share of RES in the total electric power generation by 2024.[56] This target is established for the State, but is not legally binding for electric power producers and no fines are imposed for failing to meet this target or other similar targets.

An intensive utilization of RES in Russia would provide several important benefits, including:

- Electric power supply for isolated consumers, i.e., those who do not have access to the centralized electric power distribution grids;
- Reduction of liquid fuel shipments to remote northern areas of Russia, including the Arctic region (e.g., replacing local diesel generation with RES);
- Increased reliability of the electric power supply in areas with centralized electric power distribution grids, particularly those experiencing electricity shortages;
- Reduction of air pollution caused by thermal power plants fuelled by coal or oil.

The Russian Federation joined the International Agency for Renewable Energy (IRENA) on 22 July 2015.[63] This membership allows Russia to participate in the development of international renewable energy standards and adopt best practices and advanced technologies.

SHP development and operation in Russia are regulated by the Federal Laws covering any hydropower plants, including federal laws "On the Electrical Power Energy Industry", "On Technical Regulation" and "On the Safety of the Fuel-Energy Complex Facilities", as well as by the laws and regulations regarding other RE, including the federal law "On Energy Conservation, Energy Efficiency, and Changes in Several Legislative Acts of the Russian Federation".[20,64,65,66]

The Parliament of the Russian Federation approved amendments to the Federal Law on the Electrical Power Energy Industry in 2011, which created new opportunities to use the capacity market mechanism to encourage RES growth on the wholesale market and imposed priority energy purchase on the retail market by grid companies in volumes necessary to compensate for energy losses.[20] This approach was further developed in 2013, when the Government introduced a new capacity-based scheme for supporting renewable energy facilities, including SHP plants.[67,68] This scheme provides for the financial viability of RES investment projects by concluding an agreement for the sale/purchase (supply) of capacity between RES developers and wholesale market consumers. It ensures the purchase of installed capacity of approved renewable energy installations at a regulated price for 15 years.

RES investment projects are selected for the capacity-based scheme annually on a competitive basis within the limit of total RES installed capacity approved by the authorities each year. To officially quality as an RES facility under the scheme, an investment project must comply with various qualifying criteria, including:

- The project is developed in one of the price zones of the wholesale market (i.e., projects in the non-price zones do not qualify for the scheme);
- The project's installed capacity is equal to or exceeding 5 MW but less than 25 MW;
- The project does not exceed the maximum cost established by the Government for this project;
- The project is commissioned within the agreed deadline, etc.

Recognition of a completed RES project as a qualified generating facility is carried out by the Market Council upon the owner's application.[68] The prices of installed capacity supplied by the qualified facilities under the agreement for the sale/purchase (supply) of capacity are determined by the commercial operator of the wholesale market for each generating facility specified in such agreements according to the methodology set by the Government. The feed-in tariffs (FITs) for electricity supplied to the wholesale market are calculated individually for each qualified facility based on the total investment project cost approved in the agreement. This approach ensures the return of investments into the qualified facilities over 15 years.[67]

The capacity-based approach differs from the support mechanisms in other countries, where RES are promoted based on the purchase of the electricity output (MWh) at a guaranteed FIT. The electricity output-based approach proved to be impractical in Russia due to existing regulatory and technical obstacles.

Amendments to the Federal Law "On Electrical Power Energy Industry" focused on micro-generation took effect in 2019. The amended law formalized the definition and criteria of a micro-generation facility based on RES and created a legal foundation for the development of this sector. It allows the sale of excess electricity produced through micro-generation and thus reduces the payoff period of micro-generation facilities, making them more appealing to investors. Additionally, relevant amendments made to the Tax Code suspended taxes on the revenue of individuals selling electric power until 2029.[20,69]

While there is no legislation specifically targeting or promoting SHP development, SHP projects in Russia must comply with a range of National Standards applicable to all hydropower plants regarding their development and safety. There are two National Standards, GOST R-51238-98 and GOST R-56125-2014, specifically pertaining to SHP plants, regulating some technical aspects of SHP development and applicable terminology.[22,26,70]

SHP plants with an installed capacity of below 25 MW that participate in the retail electric power market can also benefit from:

- Subsidies of the grid connection costs;
- Obligation of the grid companies to compensate for electricity losses on their network by priority purchases of electricity produced from RES;
- FITs that ensure a certain return on the investment (currently at 14 per cent);
- Obligation of grid companies to buy renewable energy despite the difference in tariffs (renewable energy tariffs are now 3.5 times higher than those for conventional energy generators).

COST OF SMALL HYDRPOWER DEVELOPMENT

SHP project costs in Russia vary depending on the design, equipment prices and construction costs. A few examples of SHP project costs are provided in Table 5.

Table 5. **Costs of Small Hydropower Projects in Russia**

Name	*Location*	*Capacity (MW)*	*Head*	*Development stage as of 1 January 2021*	*Developer*	*Estimated cost per kW in RUB (USD)*
Segozyorskaya	Segezha River	8.1	N/A	Design	En+ group	176,000 (3,000)
Beloporozhskaya -1	Kem River	24.9	13.1	Operating since 2020	AO Nord Hydro	174,000 (2,600)
Beloporozhskaya -2	Kem River	24.9	13.1	Construction completed	AO Nord Hydro	174,000 (2,600)
Bolshoi Zelenchuk	Bolshoi Zelenchuk River	9.0	9.0	Operating since 2018	PAO RusHydro	165,000 (2,800)
Krasnogorskaya -1	Kuban River	24.9	24.9	Construction started in 2019	PAO RusHydro	164,000 (2,600)
Barsuchkovskaya	Bolshoy Stavropol Canal	5.3	12.7	Operating since 2020	PAO RusHydro	155,000 (2,400)

Source: RusHydro,[49,71,72,73] Nord Hydro,[50] RDIF,[51,52] EDB[53]

The average cost of SHP projects qualified for state support in 2021–2024 as an RES is estimated at 193,465 RUB/kW (2,600.22 USD/kW), while being limited to a maximum of 194,640 RUB/kW (2,616.01 USD/kW).[74] The average cost of a project includes both capital expenditures and the average annual cost of operation. For the period up to 2024, there is a regulatory limit of 146,000 RUB/kW (1,962.28 USD/kW) on capital expenditures for construction of SHP plants officially qualified to operate in the retail markets as RES.[56]

The structure of SHP project costs varies, but the biggest share is usually represented by the project construction cost (including equipment and materials). For example, of the total funds spent on the Beloporozhskaya-1 SHP plant, 5 per cent was allocated for the design, 72 per cent for the construction, 4 per cent for other investment costs including land allocation, grid connection, etc. and the rest went towards various bank loan expenses.[75]

FINANCIAL MECHANISMS FOR SMALL HYDROPOWER PROJECTS

The main guarantee for RES investors is provided under the Federal Energy Efficiency Law regarding the determination of the special tariffs for energy efficiency investments, including RES projects.[66] Entities investing in energy efficiency improvements can keep the financial benefits resulting from these investments for a period of at least five years following the regulatory period during which these investments were implemented.

The federal law "On Electric Power Energy Industry" provides several mechanisms for supporting the development of RES in Russia.[20] By signing an agreement for the sale/purchase (supply) of capacity, investors commit to constructing a specific type of a generating facility, of a specific capacity and at a specific location. They also guarantee the availability of the respective installed capacity for electricity production. In return, investors are remunerated at regulated tariffs. Special state auctions are held each year selecting RES investment projects (wind power, solar power and SHP) under this scheme. As a result of eight competitive selections of investment projects for the construction of RES generating facilities, which took place from 2013 to 2020, only 11 applications for the construction of SHP plants were selected, with a total capacity of 168.07 MW.

There is a variety of possibilities for accessing financial support for SHP projects. Generally speaking, responsibility for developing SHP in Russia is divided between regional and municipal authorities and private investors. Regional authorities interested in the development of SHP are capable of financing studies of hydropower potential in the region, but further implementation usually depends on private investors.

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Changes in river flows are the most important climate change factor for hydropower. Changes in the global hydrological cycle have already taken place and will become more apparent in the next few decades.

Researchers from the Laboratory of Global Energy Problems of the MEI National Research University, supported by the Russian Fund for Fundamental Research, calculated changes in the climatic characteristics determining renewable energy potential, including the volume of river runoff. These studies have shown that the observed and expected climate change across most of the territory of the Russian Federation is likely to be beneficial to the main RES, including renewable hydropower.[76] However, heavier precipitation can lead to the failure of hydropower generating units, increased sedimentation in the reservoirs (consequently reducing the useful life of hydropower plants) and increased risk of dam erosion and catastrophic floods.

The average increase in the hydropower output in Russia is projected at 3–4 per cent by the middle of the 21st century, in comparison with the beginning of the century. However, this trend would not be observed in the southern mountainous areas of Russia. Climate change is expected to cause an initial increase in the water resources in this region due to melting mountain glaciers, followed by a reduction of water resources available for hydropower production.[77]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The main barrier to the development of RES projects in Russia, including SHP, is the availability of vast fossil fuel resources and the importance of the gas, oil, coal and nuclear industries to the country's economy. Other significant barriers in developing SHP projects in Russia include:

- Lack of state-supported programmes for SHP development;
- Insufficient quotas for SHP projects included in the mechanisms stimulating RES development after 2024;
- Excessive regulatory requirements for SHP projects (e.g., mostly the same as for large hydropower plants);
- Lengthy procedures for land allocation and approval for projects, which can sometime last many years;
- Excessive requirements for the provision of grid connection in the case of projects implemented by regional grid companies;
- Shortage of up-to-date scientific data on the regional SHP development potential;
- Lack of standard technical and methodological regulations, information technologies and software required for designing, constructing and operating RES generation plants;
- Lack of specialist training and skilled professionals at the regional level;
- Insufficient state support for the development of SHP technologies;
- Natural and environmental constraints, including seasonal factors (in particular, frosts and floods), locations in environmentally sensitive areas and others.

Russian investors are reluctant to finance SHP projects due to the long-term period of recoupment for such investments. Consequently, there are many cases where ongoing construction of SHP plants has been put on hold.

At the same time, several policies supporting SHP development exist in Russia, including the following:

- State support for electric power plants with installed capacity of between 5 MW and 25 MW that officially qualify as RES, including SHP plants. This threshold is expected to increase to 50 MW in order to expand financial support to a wider range of RES projects;
- A support scheme for the sale of renewable energy generating capacities to the wholesale and retail markets at the prices and in accordance with the level defined by the Government. The main purpose of such support schemes is to create economic incentives for developing the production of main and auxiliary generating equipment used in the production of electric energy using RES;
- Compensation at the regional level for transmission grid operators for power losses in their grids equal to the amount of electricity generated by the connected RES facilities;

More generally, enabling factors for SHP development in Russia also include the following:

- Only a small fraction of the potential SHP capacity of the country is actively utilized at the present, with potential locations including an abundance of formerly operational SHP sites and non-powered hydraulic infrastructure;
- Extensive historical experience with SHP development and existing technical capacity and expertise in this sector on the national level, including established technical standards;

REFERENCES

1. Russian Federation Federal State Statistics Service (2021). *Preliminary estimate of the population of the Russian Federation on 1 January 2021 and its average for 2020. Available at https://rosstat.gov.ru/folder/12781 [in Russian] (Accessed 5 July 2021).*
2. Federal State Registration, Land Registry and Mapping Service (2020). *State report on condition and use of land in the Russian Federation. Available at* https://rosreestr.ru/site/activity/gosudarstvennoe-upravlenie-v-sfere-ispolzovaniya-i-okhrany-zemel/gosudarstvennyy-monitoring-zemel/sostoyanie-zemel-rossii/gosudarstvennyy-natsionalnyy-doklad-o-sostoyanii-i-ispolzovanii-zemel-v-rossiyskoy-federatsii/ [in Russian] (Accessed 5 July 2021).
3. NatWorld.info (2018). *Topography of Russia: characteristics, map, landscape, forms and mountain systems. Available at https://natworld.info/raznoe-o-prirode/relef-rossii-osobennosti-karta-landshaft-formy-i-gory [in Russian]* (Accessed 5 July 2021).
4. Climate Change Portal, World Bank Group (2020). *Average monthly temperature and rainfall for Russia for 1901-2016*. Available at https://climateknowledgeportal.worldbank.org/country/russia (Accessed 5 July 2021).
5. Federal Service for Hydrometeorology and Environmental Monitoring of the Russian Federation (Rosgidromet) (2017). *Report on the climate risks on the territory of the Russian Federation. Available at http://cc.voeikovmgo.ru/images/dokumenty/2017/riski.pdf [in Russian]* (Accessed 5 July 2021).
6. Ministry of Natural Resources and Environment of the Russian Federation (2019). *State report on the condition and use of water resources in the Russian Federation in 2018. Available at http://www.mnr.gov.ru/docs/gosudarstvennye_doklady/gosudarstvennyy_doklad_o_sostoyanii_i_ispolzovanii_vodnykh_resursov_rossiyskoy_federatsii_v_2018_god/ [in Russian]* (Accessed 5 July 2021).
7. International Energy Agency (IEA) (2020). *Key World Energy Statistics 2020.* Available at https://www.iea.org/reports/key-world-energy-statistics-2020 (Accessed 5 July 2021).
8. Government of the Russian Federation (2020). *Energy strategy of Russia for the period up to 2035*. Available at http://static.government.ru/media/files/w4sigFOiDjGVDYT4Ig-

sApssm6mZRb7wx.pdf [in Russian] (Accessed 5 July 2021).

9. UES System Operator (2021). *Unified Energy System of Russia. Available at https://so-ups.ru/functioning/ees/ups2021/* [in Russian] (Accessed 5 July 2021).
10. UES System Operator (2010). *Agreement on parallel work of the energy systems of Republic of Kazakhstan and Russian Federation dated 23 April 2010. 23 April 2010. Available at http://so-ups.ru/fileadmin/files/company/international/Kazakhstan_and_Middle_Asia/PW_agreement.pdf [in Russian]* (Accessed 5 July 2021).
11. UES System Operator (2021). *United Energy System of Russia: Provisional results. Informational review. December 2020. Available at https://so-ups.ru/fileadmin/files/company/reports/ups-review/2020/ups_review_1220.pdf [in Russian]* (Accessed 5 July 2021).
12. RusHydro (2021). *Share capital*. Available at http://www.eng.rushydro.ru/investors/stock-market/capital/ (Accessed 5 July 2021).
13. Rosseti (2021). *Company history. Available at https://www.rosseti.ru/eng/about/history/* (Accessed 5 July 2021).
14. Federal Grid Company of the United Energy System (FGC UES) (2021). *Company overview.* Available at https://www.fsk-ees.ru/eng/investors/company_overview/ (Accessed 5 July 2021).
15. World Bank Data (2019). *Access to electricity (% of population) - Russia.* Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=RU (Accessed 5 July 2021).
16. World Bank (2019). *Doing Business.* Available at https://www.doingbusiness.org/en/data/exploretopics/getting-electricity (Accessed 5 July 2021).
17. Zmiyeva, K.A. (2020). Problems of electric power supply in the Arctic regions. *Russian Arctic, 8, 2020*. Available at https://russian-arctic.info/info/articles/elektroenergetika/problemy-energosnabzheniya-arkticheskikh-regionov/ [in Russian] (Accessed 5 July 2021).
18. SakhaEnergo (2020). *About the company. Available at https://www.sakhaenergo.ru/about [in Russian]* (Accessed 5 July 2021).
19. Ministry of Energy of the Russian Federation (2021). *Regions with a high risk of electric power supply interruption. Available at https://minenergo.gov.ru/node/264* [in Russian] (Accessed 5 July 2021).
20. Parliament of the Russian Federation (2003). *Federal Law N35-FZ from 21 February 2003 "On the Electrical Power Energy Industry". Available at https://so-ups.ru/fileadmin/files/laws/fz35_260303.pdf [in Russian]* (Accessed 5 July 2021).
21. Ministry of Energy of the Russian Federation (2020). *Ministerial Order No. 508 from 30 June 2020 "On the Scheme and Programme of the Russian United Energy System Development in 2020 – 2026". Available at https://minenergo.gov.ru/node/19166 [in Russian]* (Accessed 5 July 2021).
22. Federal Agency on Technical Regulation and Metrology (1998). *State Standard of the Russian Federation, GOST R-51238-98 "Non-traditional power engineering. Small hydropower engineering. Terms and definitions". Available at* http://docs.cntd.ru/document/1200026444 [in Russian] (Accessed 5 July 2021).
23. Association NP Marker Council (2020). *General information. Available at https://www.np-sr.ru/ru/market/wholesale/index.htm [in Russian]* (Accessed 5 July 2021).
24. Parliament of the Russian Federation (1995). *Federal Law № 147-FZ "On Natural Monopolies". Available at https://so-ups.ru/fileadmin/files/laws/fz147-170895.pdf [in Russian]* (Accessed 5 July 2021).
25. Russian Federation Federal State Statistics Service (2020). *Average consumer prices*. Available at https://rosstat.gov.ru/folder/210/document/13239 [in Russian] (Accessed 5 July 2021).
26. Federal Agency on Technical Regulation and Metrology (2003). *Technical regulation SP 58.13330.2012 "SNiP 33-01-2003. Hydrotechnical constructions. Basic provisions".* Available at http://docs.cntd.ru/document/1200094156 [in Russian] (Accessed 5 July 2021).
27. Nefedova, L. (2012). *Development of a SHP resource block in the course of preparation of GIS Renewable Sources of Energy in Russia*. Physical Problems of the Ecology. vol. 18. 2012.
28. Kiselyova, S. (2015). A*bout the Atlas of Renewable Energy of Russia*. Published in REENCON-XXI. 17-28.10.2015. Moscow.
29. Moscow State University (MSU) & Joint Institute for High Temperatures of the Russian Academy of Sciences (JIHT) (2015). *GIS renewable energy sources of Russia. SHPP map*. Available at https://gisre.ru/maps/maps-obj/mges [in Russian] (Accessed 5 July 2021).
30. Hydropower Museum (n.d.). *Map of hydropower plants in Russia*. Available at http://www.hydromuseum.ru/ru/map-of-russia-and-the-world/russia-map [in Russian] (Accessed 5 July 2021).
31. INSET (2020). *Implemented Projects*. Available at https://inset.ru/realizovannye-proekty/ [in Russian] (Accessed 5 July 2021).
32. RusHydro (2021). *Generation Capacity*. *1 January 2021. Available at http://www.rushydro.ru/activity/marketing/production/capacities/ [in Russian]* (Accessed 5 July 2021).
33. Nord Hydro (2021). *Our Assets*. Available at http://nord-hydro.ru/biznes/nashi-aktivy/severo-zapadnyj-fo/respublika-kareliya/ [in Russian] (Accessed 5 July 2021).
34. 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.
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. Russian Federation Ministry for Natural Resources (2007). *Order No. 112 from 25 April 2007, "On approval of the methodology of hydrographic zoning of the territory of the Russian Federation". Available at* http://docs.cntd.ru/document/902041604 [in Russian] (Accessed 12 July 2021).
38. Voda Rossiyi (2015). *Water Resources*. Available at http://

water-rf.ru/Вода_России [in Russian] (Accessed 12 July 2021).

39. Institute for the Energy Policy (2007). *Handbook of the renewable energy sources in Russia and local types of fuels*. P. Bezrukikh. Ed. Moscow: Institute for the Energy Policy. 2007.
40. Tourist Map of the Southern Urals (2015). *Historic and nature complex Porogi as a monument of the industrial heritage*. Available at http://www.uskaz.ru/porogi.htm (Video available from https://www.youtube.com/watch?v=qbYryZ-vLr24) [in Russian] (Accessed 12 July 2021).
41. Skorokhod Journal (2016). *Small hydropower plants in Russia*. Available at https://scorokhod.livejournal.com/80287.html [in Russian] (Accessed 12 July 2021).
42. NGCE (2021). *Surveys, 3D modelling, and design of Lykovskaya SHP for the purpose of its restoration and reconstruction. Available at https://www.ngce.ru/pg_projects308.html [in Russian] (Accessed 12 July 2021).*
43. NP Soviet Rynka (2021). *Registry of the Energy Generating Facilities in the Wholesale Market*. Available at https://www.np-sr.ru/ru/market/wholesale/registry/index.htm.
44. Tsukanov, V.I. (2017). *Prospects of the Fuel-and-Energy Complex Development in Kaliningrad Oblast. Available at http://federalbook.ru/files/TEK/Soderzhanie/TEK_16/TEK16%20Cukanov%20160216.pdf.*
45. INSET (2020). *30 years on the SHP market*. Available at https://inset.ru/ [in Russian] (Accessed 12 July 2021).
46. Ruselprom (2021). *Turnkey SHP Projects*. Available at https://www.ruselprom.ru/for-industries/gidroenergetika/malye-gidroelektrostantsii-pod-klyuch/ [in Russian] (Accessed 12 July 2021).
47. Nefregaz.ru (2020). *Russian factories will supply equipment for RusHydro SHPs in the North Caucasus region*. Available at https://neftegaz.ru/news/energy/539746-rossiyskie-zavody-postavyat-oborudovanie-dlya-malykh-ges-rusgidro-na-kavkaze/ [in Russian] (Accessed 12 July 2021).
48. Novokunskiy, A.A., Novokunskiy, A.V. & Ermilov, A.P. (2019). Revisiting unification and production of national hydropower equipment for SHPs. *Hydrotechnika, 1*, 2019. Available at https://hydroteh.ru/articles/k_voprosu_unifikacii_i_proizvodstva_otechestvennogo_gidrosilovogo_oborudovanija_dlja_malyh_ges__58/ [in Russian] (Accessed 12 July 2021).
49. RusHydro (2019). *Passport of the RusHydro innovative development programme for 2020-2026 and prospectively to 2029*. Available at http://www.rushydro.ru/upload/iblock/68a/pasport-pir-vn-8298-64-02-09-2020-ver1.PDF [in Russian] (Accessed 12 July 2021).
50. NordHydro (2021). *Development strategy. Available at https://www.nord-hydro.ru/kompaniya/strategiya-razvitiya/ [in Russian] (Accessed 12 July 2021).*
51. Russian Direct Investment Fund (RDIF) (2019). *RDIF and partners build the dam for Karelia hydropower plants*. Available at https://rdif.ru/Eng_fullNews/4292/ (Accessed 12 July 2021).
52. Russian Direct Investment Fund (RDIF) (2019). *RDIF and partners set to provide over 30% of private investments required for Russia's national projects.* Available at https://rdif.ru/Eng_fullNews/3945/ (Accessed 12 July 2021).
53. EDB (2017). *EDB and the IIB open a RUB 8.15 billion loan facility for Nord Hydro – Belyi Porog to construct small hydropower plants in Karelia. Available at https://eabr.org/en/press/news/edb-and-the-iib-open-a-rub-8-15-billion-loan-facility-for-nord-hydro-belyi-porog-to-construct-small-/?sphrase_id=104692* (Accessed 12 July 2021).
54. Government of the Russian Federation (2013). *Resolution of the Government of the Russian Federation No. 861-r dated 28 May "On changes to the main vectors of State policy in energy efficiency increase based on renewable energy sources for the period up to 2020". Available at http://government.ru/media/files/41d469e1c2560060598c.pdf [in Russian] (Accessed 12 July 2021).*
55. Government of the Russian Federation (2017). *Resolution of the Government of the Russian Federation No. 354-R from 28 February 2017 "On approval of the main vectors of State policy regarding energy efficiency in the electric power industry for the period up to 2024". Available at* http://docs.cntd.ru/document/902137809 [in Russian] (Accessed 12 July 2021).
56. Government of the Russian Federation (2020). *Resolution of the Government of the Russian Federation No. 1-r "On approval of the main vectors of State policy regarding energy efficiency in the electric power industry for the period up to 2035". Available at* http://docs.cntd.ru/document/902137809 [in Russian] (Accessed 12 July 2021).
57. Government of the Republic of Karelia (2010). *Order of the Government of the Republic of Karelia No. 271 r-P from 22 June 2010, "On the programme of prospective development of the electrical power industry in the Republic of Karelia for the period up to 2015". Available at http://docs.cntd.ru/document/919502495* [in Russian] (Accessed 12 July 2021).
58. Government of the Republic of Chechnya (2018). *List of priority investment projects in Republic of Chechnya. Available at http://docs.cntd.ru/document/543743307* [in Russian] (Accessed 12 July 2021).
59. Cleandex (2016). *Small hydropower in Russia. Available at http://www.cleandex.ru/articles/2016/01/18/hydropower8* [in Russian] (Accessed 12 July 2021).
60. AO SO EES ODU Yuga (2020). *Small Hydropower Plants of ODU Yuga. Available at http://www.yug.so-ups.ru/Page.aspx?IdP=925* [in Russian] (Accessed 12 July 2021).
61. Kuvalkin, A.V., Bondarenko, V.L, Lebedeva, E.B. & Kuvalkin, A.A. (2012). Estimate of the economic potential of SHP development in Rostov oblast. *Scientific magazine of Russian Irrigation Research Institute, 3(07), 2012, pp.145-155. Available at http://staff.tiiame.uz/storage/users/136/articles/FMQvDDMBaQd4BL9WoIMXH7qUhfVyeITmaBovKrjC.pdf* [in Russian] (Accessed 12 July 2021).
62. RIA Novosti (2019). *Medvedev signs a decree on ratification of the Paris Agreement*. Available at https://ria.ru/20190923/1559003977.html [in Russian] (Accessed 5 July 2021).
63. Ministry of Energy of the Russian Federation (2015). *Russia joins the International Agency for Renewable Energy IRENA*. 22 July 2015. Available at http://minenergo.gov.ru/node/2334 [in Russian] (Accessed 12 July 2021).
64. Parliament of the Russian Federation (2002). *Federal Law No. 184-FZ from 27 December 2002 "On technical regula-*

tion". Available at https://so-ups.ru/fileadmin/files/laws/fz184-271202.pdf [in Russian] (Accessed 12 July 2021).

65. Parliament of the Russian Federation (2011). *Federal Law No. 256-FZ from 21 July 2011 "On the safety of the fuel-energy complex facilities". Available at https://so-ups.ru/fileadmin/files/laws/fz256-210711.pdf* [in Russian] (Accessed 12 July 2021).
66. Russian Federation Parliament (2009). *Federal Law No. 261-FZ from 23 November 2009 "On energy conservation, energy efficiency and changes in several legislative acts of the Russian Federation"*. Available at https://beta.docs.cntd.ru/document/902186281 [in Russian] (Accessed 12 July 2021).
67. Government of the Russian Federation (2013). *Decree of the Government of the Russian Federation No. 449 from 28 May 2013 "On the Mechanism for the Promotion of Renewable Energy on the Wholesale Electricity and Capacity Market".* Available at http://www.consultant.ru/document/cons_doc_LAW_146916/ [in Russian] (Accessed 12 July 2021).
68. Government of the Russian Federation (2020). *Decree of the Government of the Russian Federation No. 1298 from 29 August 2020, "On issues of stimulating the use of renewable energy sources, amending some acts of the Government of the Russian Federation, and recognising the expiration of certain provisions of certain acts of the Government of the Russian Federation".* Available at http://www.garant.ru/products/ipo/prime/doc/74487394/ [in Russian] (Accessed 12 July 2021).
69. Pominova, I. (2019). *Renewable generation no rival to traditional facilities in Russia.* Analytical Center for the Government of the Russian Federation. Available at https://ac.gov.ru/en/comments/comment/26519 (Accessed 12 July 2021).
70. Standartinform (2015). *National Standard of the Russian Federation GOST R 56125-2014, "Renewable power engineering. Hydropower engineering. Electromechanical equipment guide for small hydroelectric installations." Available at https://beta.docs.cntd.ru/document/1200113325* [in Russian] (Accessed 12 July 2021).
71. RusHydro (2014). *RusHydro started construction at the site of Bolshoy Zelenchuk SHP. Available at http://www.rushydro.ru/press/news/90324.html* [in Russian] (Accessed 12 July 2021).
72. RusHydro (2017). *Report on the public technological and financial audit of Krasnogorskaya GES-1 investment project*. Available at http://www.rushydro.ru/upload/iblock/46a/001_Otchet_TTsA-KMGES-1.pdf [in Russian] (Accessed 12 July 2021).
73. RusHydro (2020). *SHP Barsuchkovskaya. Available at http://www.kkges.rushydro.ru/hpp/bars/barsuchkovskaya-malaya-ges* [in Russian] (Accessed 12 July 2021).
74. NP Soviet Rynka (2020). *Results of selection of renewable energy projects for 2021, 2022, 2023 and 2024 are available*. Available at https://www.np-sr.ru/ru/press/news/50472-podvedeny-itogi-otbora-proektov-vie-na-2021-2022-2023-i-2024-gody [in Russian] (Accessed 12 July 2021).
75. Nord Gidro (2016). *Construction plan for the Beloporozhskiye HPPs*. Available at http://www.premiya-razvitiya.ru/files/2017-i3-prezentatsiya.pdf [in Russian] (Accessed 22 March 2022).
76. Subbotin, A. (2020). *Changes in climate are favouring development of renewable energy.* Available at https://poisknews.ru/themes/ekonomika-themes/pogoda-balu-et-izmeneniya-klimata-blagopriyatstvuyut-razvitiyu-vozobnovlyaemoj-energetiki/ [in Russian] (Accessed 12 July 2021).
77. Klimenko, V.V., Teryoshin, A.G. & Fedotova, E.V. (2019). Increase in renewable energy potential in Russia in the context of global warming. Scientific and Technical Publications of St. Peterburg Polytechnical University, *Natural and Technical Sciences 25*(3), pp. 6–27. Available at https://cyberleninka.ru/article/n/rost-potentsiala-vozobnovlyaemyh-istochnikov-energii-v-rossii-v-usloviyah-globalnogo-potepleniya [in Russian] (Accessed 12 July 2021).

Slovakia

International Center on Small Hydropower (ICSHP)

KEY FACTS

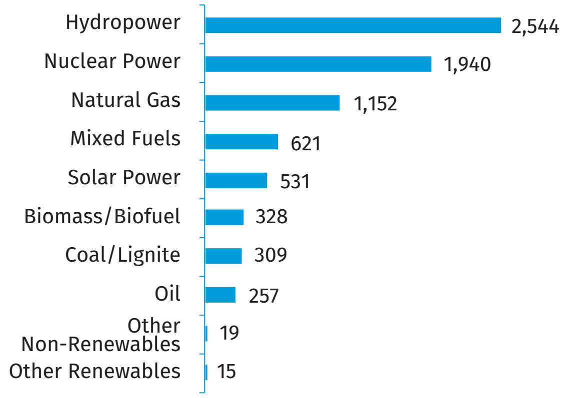
Population	5,458,827 (2020)[1]
Area	49,035 km2 [2]
Topography	The terrain of Slovakia is predominately mountainous with some lowlands in the south. The Carpathian Mountains occupy the majority of the country, sweeping from east to west. The highest elevations are found in the High Tatra and Low Tatra subranges in the central region. The highest point, Gerlachovský Peak, at 2,655 metres, is located in the High Tatra Mountains close to the border of Poland. Along the southern border with Hungary are the Little Atfold lowlands in the south-west and the Eastern Slovakian Lowland in the south-east, which make up part of the Inner Carpathian Depressions.[2]
Climate	Slovakia has a moderate continental climate, with some variations between regions. The northern, mountainous region is colder with snow remaining on the summits of the highest peaks into the summer. In the southern regions where most of the population resides, there are four distinct seasons. The average temperature in July is approximately 20 °C and in January temperatures can reach close to –5 °C.[2]
Climate Change	Over the last century, average air temperatures in Slovakia have increased significantly, by 2 °C along with some less significant increases in precipitation. By 2100, average temperatures are expected to increase by an additional 1.5–4.7 °C throughout the whole country. Average precipitation is expected to increase in the northern regions, especially in the winters and decrease in the southern regions, especially in the summers.[3]
Rain Pattern	Annual rainfall varies between regions. The northern regions experience the most precipitation, with an average of 1,100 mm per year with some places surpassing 2,000 mm per year. In the southern regions, annual precipitation is approximately 570 mm. Precipitation is experienced throughout the year with a slight increase during the summer months and a slight decrease during the winter months. During winters, precipitation is usually in the form of snow.[2]
Hydrology	The rugged terrain of Slovakia is home of many rivers and mountain lakes. Many of the rivers flow southwards into the Danube, the country's most important river. The river separates into other channels as it flows south-westwards while its main channel continues on to form the border with Hungary. The Little Danube, one of the channels, branches east and then south-east to meet the Váh and Nitra Rivers. Other major rivers that flow into the Danube and its channels are Hron and Ipel. Many of the main rivers in the eastern region of the country, such as the Hornád, the Bodrog and the Torysa, flow southwards into Hungary. The Poprad, also in the east, is the only sizable river that flows northwards, into Poland. River flows tend to be strongest during early spring and lowest at the end of summer.[2]

ELECTRICITY SECTOR OVERVIEW

In 2020, the total installed capacity in Slovakia was 7,716 MW, of which over 44 per cent was with renewable energy sources. Hydropower accounted for 2,544 MW (33 per cent), nuclear power for 1,940 MW (25 per cent), natural gas for 1,152 MW (15 per cent), mixed fuels for 621 MW (8 per cent), solar power for 531 MW (7 per cent), biomass/biofuel for 328 MW (4 per cent), coal/lignite for 309 MW (4 per cent), oil for 257 MW (3 per cent) and the remaining 1 per cent was split between other non-renewable sources for 19 MW and other renewable sources for 15 MW (Figure 1).[4] Total installed capacity has been gradually decreasing in the past decade, due to the elimination of much of the coal and lignite capacities. In 2019, the Government announced that coal and lignite would be completely phased out by 2023.[5] To compensate for the closures, the nuclear plant at Mochovce is currently undergoing expansion.[6]

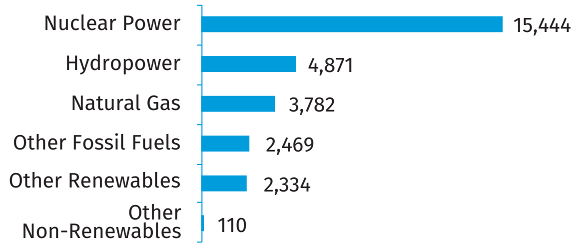
In 2020, the total electricity generation in Slovakia was 29,010 GWh, of which, 25 per cent was with renewable energy sources. Nuclear power generated the majority, at 15,444 GWh (53 per cent), hydropower 4,871 GWh (17 per cent), natural gas generated approximately 3,782 GWh (13 per cent), other fossil fuels, including coal, oil and mixed fuels, 2,469 GWh (9 per cent), other renewable sources, including solar power, biomass and wind power, 2,334 GWh (8 per cent) and other non-renewable sources 110 GWh (0.3 per cent) (Figure 2). Slovakia has been a net importer of electricity since 2007 and in 2020, net imports were 318 GWh, much lower than previous years.[7] Total imports amounted to 13,288 GWh, mostly from the Czech Republic and Poland, and total exports amounted to 12,970 GWh, mostly to Hungary and Ukraine. Total domestic electricity consumption was 29,328 GWh.[4] The electrification rate of Slovakia is 100 per cent.

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



Source: SEPS[4]

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



Source: SEPS[7]

The electricity sector in Slovakia began restructuring in 2000 and completed its liberalization process in 2006, when Italian company, Enel closed its purchase of 66 per cent of the previously state-owned electricity supplier, Slovenské elektrárne (SE) with the remaining shares kept by the state.[6] Since then, other private companies have been able to produce and sell electricity, however, SE still represents the largest market shares. In 2020, SE owned and operated over 53 per cent of the country's installed capacity and generated over 65 per cent of the total electricity.[8]

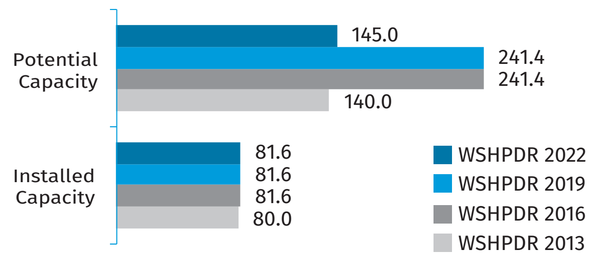
There are three regional Distribution System Operators (DSO) that are 51 per cent state-owned — Západoslovenská energetika, a.s. (Western Slovak Power Utility), Stredoslovenská energetika, a.s. (Central Slovak Power Utility) and Východoslovenská energetika, a.s. (Eastern Slovak Power Utility). The entire transmission network is operated by state-owned Slovenská elektrizačná prenosová sústava (SEPS). The country's power system is integrated into the European Network of Transmission System Operators (ENTSO-E). Transmission lines cross national borders with the Czech Republic, Hungary and Poland, which facilitates trade between the countries. In 2019, an agreement was made between SEPS, Západoslovenská energetika and Hungarian distribution company, E.ON Észak-dunántúli Áramhálózati, to begin the Danube InGrid project that will create a smart grid between the two countries with an aim to appropriately balance the increase of renewable energy sources with energy consumption.[5]

Electricity prices for the final consumer include a network fee, a value-added tax (VAT) and the supplier price. The Regulatory Office for Network Industries (RONI) is the sector's regulatory body and determines the network fees.[8] In 2020, the average price of electricity for medium-sized households was 0.1686 EUR/kWh (0.18 USD/kWh), which was approximately 20 per cent lower than the European Union (EU) average. The average price for non-household consumers was 0.0977 EUR/kWh (0.10 USD/kWh), which was slightly above the EU average.[9]

SMALL HYDROPOWER SECTOR OVERVIEW

Small hydropower (SHP) is defined in Slovakia as plants with a capacity of 10 MW or less. Total SHP installed capacity is 81.6 MW according to the most recent accurate data available.[10] Potential capacity is 145 MW based on planned SHP development, indicating that approximately 56 per cent of the total potential has been developed.[11] Compared to the data from the *World Small Hydropower Development Report (WSHPDR) 2019*, installed capacity has remained the same while potential capacity has decreased due to an updated plan by the Government to develop a total of 145 MW rather than the previously planned 241.4 MW (Figure 3).

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



Sources: Energie 21,[10] *WSHPDR 2019*,[12] *WSHPDR 2016*,[13] *WSHPDR 2013*[14]

Slovakia has a long history of SHP, beginning in the late 19th century. Many of the earlier plants were originally purposed to power individual industrial plants and factories wherein some simply used the hydraulic energy produced with water wheels while some also produced electricity. Eventually, many of the plants were connected to the grid to provide electricity to the population by the state-owned SE.[15] There are now 217 SHP plants throughout the country ranging from less than 100 kW to 10 MW (Table 1).[10] Since the privatization of the sector, the majority of today's SHP plants are operated by small, private companies with the exception of a few owned by SE (Table 2).[8]

Table 1. **Small Hydropower in Slovakia**

Capacity	*Number of plants*	*Installed capacity [MW]*	*Generation [GWh/year]*
< 0.1 MW	118	4.586	19.56
0.1 MW to 1 MW	78	32.34	124.06
1 MW to 10 MW	21	44.71	138.18
Total	**217**	**81.636**	**281.8**

Source: Energie 21[10]

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

Name	*Installed capacity (MW)*	*Operator*	*Launch year*
Dobšiná III	0.32	SE	2014
Dobšiná II	2.0	SE	1994
Veľké Kozmálovce	5.32	SE	1988
Čierny Váh flow	0.76	SE	1982
Tvrdošín	6.10	SE	1979
Bešeňová	4.64	SE	1976
Ružín II	1.80	SE	1974
Krompachy	0.33	SE	1932
Švedlár	0.09	SE	1924
Rakovec	0.50	SE	1913

Source: SE[8]

In 2011, the Government published the Plan for Hydroenergy Power Utilization in Slovakia, which planned for the new construction of up to 368 SHP plants totalling 160 MW by 2030, bringing the total installed capacity of SHP to 241 MW.[12] However, pressure to maintain the ecological sustainability of rivers has caused many rivers to gain protection status as well as the enforcement of environmental impact assessments (EIA) to be carried out. In recent years, this has led to the delay or cancellation of some projects. In some cases, such as the planned Hronský Beňadik project, the country's Supreme Court had to put a stop to construction after learning that investors did not properly undergo an EIA. Local non-governmental organizations (NGOs) have also got involved, pushing to cancel all projected planned on the Hron River.[16] The more recent, Integrated National Energy and Climate Plan 2021–2030 published in 2019 still foresees further SHP development, but at levels lower than the 2011 plan. This plan expects that the total installed capacity of all types of hydropower will amount to 2,671 MW by 2030, in which 145 MW of it would be SHP.[11]

RENEWABLE ENERGY POLICY

The objectives of the 2014 Energy Policy of Slovakia are to ensure an affordable, environmentally sensitive and reliable supply of electricity for all consumers. This plan envisaged a 24 per cent renewable energy share in electricity generation by 2020 and 27 per cent by 2030.[17] In 2020, the actual share of renewable energy electricity generation was 25 per cent, slightly surpassing the first milestone. The more recent Integrated National Energy and Climate Plan published in 2019 focuses on the aim for a low-carbon circular economy by 2050. Renewable energy objectives include the 27 per cent in electricity generation as in the previous plan and a 19.2 per cent share in final consumption by 2030. More specifically, this plan outlines individual targets of installed capacity and generation of each renewable energy source. By 2030, the proposed respective capacity and generation of hydropower are 2,671 MW and 5,322 GWh; of solar power are 1,200 MW and 1,260 GWh, which will be focused to provide decentralized power to homes and buildings; of wind power are 500 MW and 1,000 GWh and of biomass/biofuel are 400 MW and 2,540 GWh. There will also be an inclusion of 4 MW and 30 GWh of geothermal energy, which is set to first appear in 2024.[11]

To promote renewable energy on the grid, renewable energy sources have priority connection to the electricity system, are eligible for feed-in tariffs (FITs) and can get investment support during construction. A 2020 amendment to the 2018 Renewable Energy Act stipulates that FITs are to be available for solar power installations above 100 kW and to all other renewable energy installations above 500 kW. It also introduces green auctions that can be available for new solar power installations between 100 kW and 2 MW and all other renewable energy installations between 500 kW and 10 MW.[18]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

The main barriers to SHP development in Slovakia include:

- Other renewable energy sources, such as biomass, biogas and solar photovoltaic, have a shorter payback period than SHP plants;
- Administrative barriers are discouraging to investors due to the construction of hydropower plants in Slovakia having a long legislative process. When private developers identify a suitable location for the plant, the permission procedure to comply with the Slovak Building Act demands zoning planning documentation and additional documentation;

- Environmental regulations require investors to obtain a permission according to the Slovak Water Act and an approval from various environmental organizations. This includes carrying out a comprehensive EIA;
- There is a mistrust towards the construction of SHP plants from the general public and environmental activists.[12,16]

The main enablers for SHP development in Slovakia include:

- Financial incentives such as FITs and green auctions are in place for new installations of hydropower between 500 kW and 10 MW;
- SHP potential in the country has not yet been reached, presenting opportunities for new SHP projects;
- Presence of political will exemplified in national plans that include increasing the country's SHP installed capacity to 145 MW by 2030, proving that new construction is encouraged during these next few years.[11,18]

REFERENCES

1. World Bank (2020). *Population, total – Slovak Republic.* Available at https://data.worldbank.org/indicator/SP.POP.TOTL?locations=SK (Accessed 20 June 2022).
2. Encyclopædia Britannica (2022). *Slovakia.* Available at https://www.britannica.com/place/Slovakia (Accessed 20 June 2022).
3. Ministry of the Environment (2017). *The Seventh National Communication of the Slovak Republic on Climate Change.* Available at https://unfccc.int/sites/default/files/resource/976840315_Slovakia-NC7-1-7NC_SVK.pdf (Accessed 20 June 2022).
4. Slovenská elektrizačná prenosová sústava (SEPS) (2020). *Slovak Electric Power Dispatching 2020.* Available at https://www.sepsas.sk/media/4951/rocenka-sed-2020.pdf (Accessed 20 June 2022).
5. Powering Past Coal Alliance (PPCA) (2020). *Slovakia Coal Phase Out.* Available at https://www.poweringpastcoal.org/members/slovakia (Accessed 20 June 2022).
6. Slovenské elektrárne (SE) (n.d.). *About Us.* Available at https://www.seas.sk/en/about-us/ (Accessed 20 June 2022).
7. Slovenská elektrizačná prenosová sústava (SEPS) (2021). *Individual and Consolidated Annual Report 2020.* Available at https://www.sepsas.sk/media/5031/seps-en-2020-final.pdf (Accessed 20 June 2022).
8. Slovenské elektrárne (SE) (2020). *Annual Report 2020.* Available at https://www.seas.sk/wp-content/uploads/2022/05/annual-report-2020.pdf (Accessed 20 June 2022).
9. Eurostat (2022). *Electricity Prices by Type of Consumer.* Available at https://ec.europa.eu/eurostat/databrowser/view/ten00117/default/line?lang=en (Accessed 20 June 2022).
10. Energie 21 (2020). *Malé vodné elektrárne na území Slovenska.* Available at https://energie21.cz/male-vodne-elektrarne-na-uzemi-slovenska/ [in Slovak] (Accessed 21 June 2022).
11. Ministry of Economy of the Slovak Republic (2019). *Integrated National Energy and Climate Plan 2021 – 2030.* Available at https://ec.europa.eu/energy/sites/ener/files/sk_final_necp_main_en.pdf (Accessed 21 June 2022).
12. 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.
13. 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.
14. 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.
15. International Water Power (2006). *Slovakian Developments.* Available at https://www.waterpowermagazine.com/features/featureslovakian-developments/ (Accessed 21 June 2022).
16. Euractiv (2022). *Slovensko nemapuje povodňové riziká a pri vodných elektrárňach porušuje pravidlá*. Available at https://euractiv.sk/section/klima/news/komisia-slovensko-nemapuje-povodnove-rizika-a-pri-malych-vodnych-elektrarnach-porusuje-pravidla/ [in Slovak] (Accessed 21 June 2022).
17. Ministry of Economy of the Slovak Republic (2014). *Energy Policy of the Slovak Republic*. Available at https://www.mhsr.sk/uploads/files/47NgRIPQ.pdf (Accessed 22 June 2022).
18. CMS Law (2020). *Renewable Energy Law and Regulation in Slovakia.* Available at https://cms.law/en/int/expert-guides/cms-expert-guide-to-renewable-energy/slovakia (Accessed 22 June 2022).

Ukraine

Dmytro Stefanyshyn, Institute of Telecommunications and Global Information Space

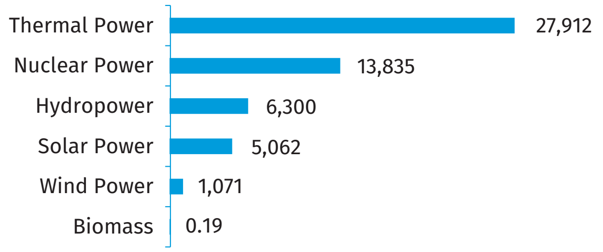
KEY FACTS

Population	44,385,155 (2019)[1]
Area	603,549 km^2 [2]
Topography	Ukraine is a country of plains, with most of its land located below a 300 metre altitude. Mountainous areas such as the Ukrainian Carpathians and the Crimean Mountains occur only on the country's borders and account for less than 5 per cent of its area. The highest point is Mount Hoverla in the Carpathians, at 2,061 metres above sea level.[2]
Climate	Ukraine has a temperate climate influenced by moderately warm, humid air from the Atlantic Ocean. Winters, lasting from November to March, are considerably milder in the west than in the east. On the other hand, during the summer, lasting from May to September, the east often experiences higher temperatures than the west. Average annual temperatures range from 5.5–7 °C in the north to 11–13 °C in the south. The average temperature in January, the coldest month, is approximately -3 °C in the south-west and -8 °C in the Carpathians and north-east. The average temperature in July, the hottest month, is approximately 23 °C in the south-east and south, 18 °C in the north-west and 19 °C in the Carpathians.[2,3]
Climate Change	Among the main effects of climate change in Ukraine are warmer winters and the frequent absence of a seasonal snow cover in much of the country. Extreme weather events such as heatwaves and summer droughts are also becoming more common. The incidence of droughts has nearly doubled in the last 20 years.[4] Rivers in Ukraine are experiencing declining runoff and droughts are expected to become more frequent in the coming years.[5,6]
Rain Pattern	Annual precipitation averages 565 mm.[5] Precipitation is uneven across the country, with two to three times as much precipitation occurring during the warmer season as during the cold season.[2] The average annual precipitation ranges from between 600 and 650 mm in the west and north-west to 300 mm in the south and south-east.[3] The highest annual precipitation occurs in the Carpathians (1,500 mm).[2,3]
Hydrology	Ukraine is subdivided into three major hydrological zones—the plain-covered part, the Ukrainian Carpathians and the Crimean Mountains.[6] Almost all of the country's major rivers flow from north-west to south-east through the plains to empty into the Black Sea and the Sea of Azov.[2] The longest river is the Dnieper, approximately 2,201 km in length, of which 980 km are in Ukraine; the Dnieper drainage basin covers 65 per cent of the country's surface area.[3,2,5] In the plain part of Ukraine, the density of the river network varies significantly: with 0.1–0.2 km/km^2 in the south, 0.25–0.5 km/km^2 in the mixed-forest zone in the north and 0.4–0.8 km/km^2 in the forest-steppe zone. The surface runoff varies from 0.2–0.5 l/s from 1 km^2 in the south, with some rivers drying out in the summer, to 3.0–4.5 l/s from 1 km^2 in the north. In the Ukrainian Carpathians, the density of the river network is 1.0 km/km^2 or more. The surface runoff of the Carpathian rivers varies from 15 to 25 l/s from 1 km^2 and reaches 35 l/s from 1 km^2 in the upper reaches of the Tysa River. In the Crimean Mountains, the density of the river network reaches 0.6–0.7 km/km^2 and surface runoff varies from 26 to 0.37 l/s from 1 km^2. In this region, the hydrological regime is unstable and some rivers dry up.[6] In total, more than 63,000 rivers and streams flow in Ukraine, with 93 per cent of them being less than 10 km in length.[3] There are also 1,103 reservoirs in Ukraine, with a total water volume of approximately 55,500 million m^3, and 50,793 artificial ponds (reservoirs with a capacity not exceeding 1 million m^3) with a total water volume of 3,969.4 million m^3.[5,7]

ELECTRICITY SECTOR OVERVIEW

The total installed capacity of power plants in Ukraine as of November 2020 was 54,365 MW.[8] Of the total, 51 per cent came from thermal power (including combined heat and power) plants and almost 26 per cent from nuclear power plants. Thus, thermal and nuclear power accounted for more than 75 per cent of the country's total installed capacity. The remaining 23 per cent was derived from renewable energy, with both large and small hydropower (SHP) plants and pumped-storage hydropower providing approximately 12 per cent, and other renewable energy sources providing also approximately 12 per cent (Figure 1).[8]

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

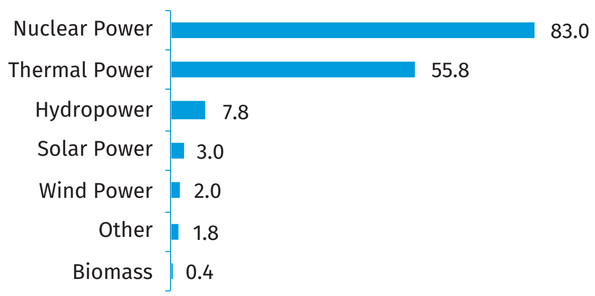


Source: Ukrenergo[8]

Notes: Data are for November 2020 and do not include the fourth hydropower unit with an installed capacity of 324 MW at the Dniester pumped-storage hydropower plant that was commissioned in December 2020. The data exclude the temporarily occupied Autonomous Republic of Crimea, the city of Sevastopol and uncontrolled parts of the Donetsk and Luhansk regions.

In 2019, the total annual electricity generation in Ukraine amounted to 153.8 TWh.[9] Electricity generation had been rising for two years, from 154.82 TWh in 2016 to 159.3 TWh in 2018, but decreased steeply in 2019 by 5.4 TWh compared to 2018.[3,9] This decrease was due to an overall reduction in electricity consumption as well as a decline in the country's industrial output.[9] In particular, there was a decrease in electricity production from nuclear and thermal power plants. On the other hand, the production of electricity from renewable sources doubled, increasing by 2.8 TWh.[9] However, the main sources of electricity generation in 2019 were still nuclear (54 per cent) and thermal (36 per cent) power plants. Hydropower and other renewable energy sources accounted for 5 per cent and 4 per cent of the total electricity generation, respectively (Figure 2).[9]

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



Source: Ukrenergo[9]

Ukraine imports approximately 83 per cent of its domestically consumed oil supplies, 33 per cent of natural gas and 50 per cent of coal. At the same time, the country's energy sector is diversified, as no fuel represents more than 30 per cent of the energy mix. Overall, domestic production covers almost 65 per cent of the total energy needs of Ukraine.[10]

Hydropower also plays a key role in the country's energy mix, represented primarily by large-scale hydropower plants (HPPs) and pumped-storage hydropower plants (PSHPs). The latter cover peak loads, control frequency and power and provide a mobile emergency reserve of power for the Integrated Power System (IPS) of Ukraine.[3,11,12] Today, there are 10 large HPPs (with installed capacity over 10 MW) in Ukraine. Six of them, with 3,908.44 MW of combined installed capacity, are located on the Dnieper, two HPPs operate on the Dniester (742.8 MW), one HPP on the Tereblya and Rika Rivers (27 MW) and one on the Southern Bug (11.5 MW).[9] Moreover, three large PSHPs with 1,609.5 MW of combined installed capacity have been commissioned: Kyiv PSHP (235.5 MW), Dniester PSHP (972 MW) and the first two units of the Tashlyk PSHP (302 MW). Large hydropower provides over 98 per cent of all hydropower production in Ukraine. At the same time, the share of hydropower in the renewable energy mix of Ukraine decreased almost twice between 2010 and the first quarter of 2020, from 98.4 per cent to 44.9 per cent.[13] This was a result of an increase in installed capacity of other renewable energy technologies, mainly solar power (Figure 1).

The IPS of Ukraine is central to the country's electric power industry. The IPS consists of power plants, substations, trunk/main power transmission and distribution lines (Table 1). The state-owned Enterprise National Power Company Ukrenergo is responsible for the operational and technological control of the IPS and the transmission of electricity via trunk power lines from the generating plants to the distribution networks.[3,9] The total amount of electricity transmitted by the Ukrenergo network amounted to 95.2 TWh in 2019.[9] The electrification rate in Ukraine is 100 per cent.[9,14] All consumers and producers can easily connect to the country's power grid. The biggest consumer of electricity is the industrial sector, accounting for 42.6 per cent of consumption in 2019.[9] Residential and public utility sectors together consume approximately 41.8 per cent of the total (Figure 3). Additionally, Ukraine ensures electricity exchange with the energy systems of other European countries (Table 2).[9]

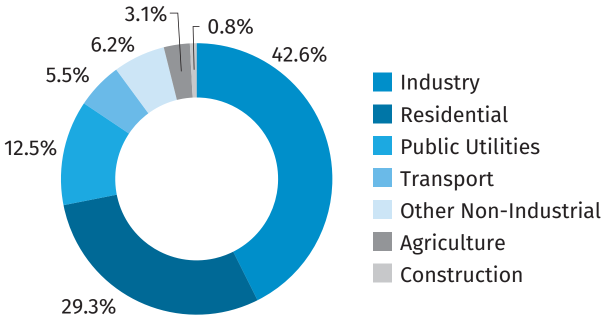
Table 1. **Main Networks of Ukrenergo in 2019**

Voltage class	*Length of power lines (km)*	*Substations*	
		Number	*Power (MVA)*
750 kV	4,403	9	18,736
500 kV	375	2	1,753
400 kV	339	2	2,008
330 kV	12,980	88	49,598
220 kV	3,019	33	9,207
110 kV	458	6	376
35 kV	122	-	-
Total	**21,696**	**140**	**81,678**

Source: Ukrenergo[9]

Note: 34 substations are located in the temporarily occupied and uncontrolled territories.

Figure 3. **Electricity Consumption in Ukraine by Sector in 2019 (%)**



Source: Ukrenergo[9]

Table 2. **Export and Import of Electricity in Ukraine in 2019 (TWh)**

Country	*Export*	*Import*
Belarus	0.0	0.9
Hungary	3.9	0.6
Moldova	0.6	0.0
Poland	1.4	0.0
Romania	0.4	0.02
Russian Federation	0.0	0.3
Slovakia	0.1	0.9
Total	**6.5**	**2.7**

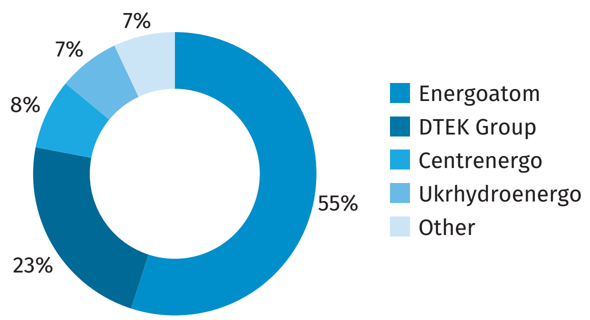
Source: Ukrenergo[9]

As of the end of 2019, 53 per cent of electrical equipment of the Ukrenergo substations had been in operation for over 25 years, 66 per cent of power transmission lines for more than 50 years and almost 5 per cent of 220–750 kV transmission lines needed complete replacement or reconstruction. The average service life of basic electrical equipment (autotransformers, limiters, compressors) is 25 years and that of power lines is 50 years. A total of 72 technological violations occurred in the Ukrenergo network in 2019. Thirty-three violations occurred due to natural disasters and outside interference, 10 violations due to erroneous actions of staff and deficiencies in maintenance and 29 due to other reasons. Technological losses during the transmission of electricity through the main networks amounted to 3.6 TWh.[9]

The Government of Ukraine plans to develop the electricity sector based on the Energy Strategy of Ukraine for the period until 2035 "Safety, Energy Efficiency, Competitiveness" (from 15 March 2006).[15] The essential task of the Energy Strategy is to reduce the energy consumption of the economy by half by 2035 and to boost the production of both traditional and alternative renewable energy sources. According to the document, total electricity production is to increase to 195 TWh, including an increase in nuclear power production to 94 TWh (48 per cent of the total), in wind and solar power generation to 25 TWh (13 per cent) and in hydropower to 13 TWh (7 per cent). The remaining 63 TWh (32 per cent) is to be produced by thermal power plants. The said document also includes the integration of the IPS of Ukraine into the European Network of Transmission System Operators for Electricity, ENTSO-E.[15] The main vectors of the country's hydropower development are also considered in the Hydropower Development Programme for the period until 2026.[11] In particular, this Programme provides for the completion of the Dniester and Tashlyk PSHPs, the construction of the Kaniv PSHP and the Kakhovka HPP-2, the construction of six new HPPs on the Dniester River as well as rehabilitation and construction of numerous SHP plants.[11,12]

According to the current legislation of Ukraine, nuclear power plants, large HPPs, PSHPs and main transmission power networks of the IPS are state-owned enterprises.[16] The main electricity producer in the country is Energoatom, a state-owned company. The main player in the hydropower sector is Ukrhydroenergo, likewise a state-owned company. One of the key players in the country's thermal power generation is the state-owned Centrenergo (Figure 4).[17] At the same time, the majority of thermal power plants, all non-traditional renewable energy plants and, in particular, SHP plants, are privately owned.

Figure 4. **Share of Electricity Generation by Producer in Ukraine in 2019 (%)**



Source: OECD[17]

Ukrhydroenergo operates the Dnieper and Dniester cascades of large HPPs and PSHPs. The Tashlyk PSHP is operated by Energoatom. The SHP sector in Ukraine is dominated by numerous domestic companies (LLC "HIDROENERHOINVEST", LLC "ENERHOINVEST", FEA "NOVOSVIT", LLC "RENER" and others) as well as foreign private stakeholders, including Norway's AICE Hydro A/S and Austria's ANDRITZ Hydro, a subsidiary of ANDRITZ Technology Group.[17,18] The main incentive for foreign players to invest in this segment of the energy sector of Ukraine is eligibility for the country's feed-in tariff (FIT) for SHP. One of the major players in the wind power segment is DTEK Renewables, the operating company that manages the DTEK Energy Group's assets in the renewable energy sector. In turn, DTEK Energy is one of the main stakeholders in thermal power. DTEK Renewables is also a key solar power producer in Ukraine.[17] Additionally, DTEK Energy exports electricity to countries of the European Union (EU) through the Burshtyn Island thermal power plant ("Island"). The "Island" is connected to the European ENTSO-E network and functions separately from the main part of the IPS.[3,9] The privately-owned SEC Biomass Ltd. and SALIX Energy represent key biomass producers in the country.[17]

The key institutions governing the energy sector of Ukraine and providing a regulatory framework include the Cabinet of Ministers of Ukraine (CMU), the Ministry of Energy and Coal Industry (MECI) and the National Energy and Utilities Regulatory Commission (NEURC). The CMU supervises state policy in the energy sector and electricity industry, while the MECI is responsible for energy policy formation and implementation, including the development of the Energy Strategy of Ukraine for the period until 2035, tracking and monitoring results and submitting annual progress reports to the CMU and the National Security and Defence Council. The MECI additionally reports to the Verkhovna Rada (parliament) and the Presidential Office. Along with the CMU and the MECI, the NEURC plays a central role in regulating the country's energy sector, especially in setting tariff policies and formulating energy prices.[3,17,19]

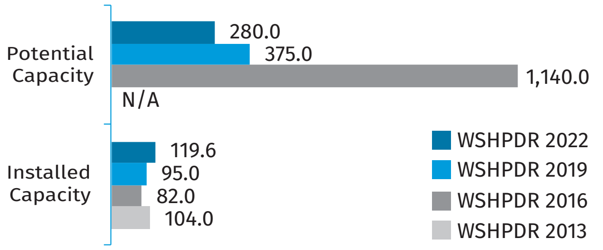
Tariffs for electricity consumers in Ukraine differ for household and non-household (industrial) consumers. For household consumers, a flat nationwide tariff of UAH 1.68 (USD 0.06) per 100 kWh, inclusive of VAT, was set as of 1 January 2021, replacing previous discounted tariffs for several categories of consumers.[20] For non-household consumers, tariffs are set individually by the electricity provider, of which there are typically one or several per administrative region. Additionally, tariffs are set according to one of two voltage classes: first class, which covers consumers connected to lines of 27.5 kV and above, and second class, which covers consumers connected to lines of below 27.5 kV. Prices (exclusive of VAT) range between UAH 16.27 and UAH 344.48 UAH (USD 0.59–12.41) per 1,000 kWh for first-class consumers and between UAH 245.09 and UAH 1508.28 (USD 8.83–54.34) per 1,000 kWh, varying across providers and regions.[21,22]

SMALL HYDROPOWER SECTOR OVERVIEW

Ukraine defines SHP as hydropower plants with less than 10 MW of installed capacity.[16,19] Additionally, hydropower facilities with less than 200 kW of installed capacity are classified as micro-hydropower and those within the 200 kW–1 MW range as mini-hydropower. This classification is related to the establishment of the FITs value. The FIT is the largest for SHP plants with a capacity of up to 200 kW and the smallest for SHP plants with a capacity of 1 MW or more.[18,23]

In 2020, there were 167 SHP plants in Ukraine with a total installed capacity of 119.618 MW.[18,24,25] The potential is estimated at 280 MW, indicating that approximately 42.7 per cent of known potential has been developed.[26] Compared to the *World Small Hydropower Development Report (WSHPDR) 2019*, the installed capacity increased by 25.9 per cent and potential capacity decreased by 25.3 per cent (Figure 5). The increase in installed capacity has been due to recently-commissioned new SHP plants; in particular, 15 new plants were commissioned in 2019 (Table 3). The estimate of potential capacity has been revised downwards in response to a 2019 study of potential SHP capacity in Ukraine carried out by the World Bank.[26]

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



Source: *WSHPDR 2019*,[3] Energo.ua,[18] Stefanyshyn,[24] RENER Group,[25] World Bank,[26] *WSHPDR 2013*,[27] *WSHPDR 2016*[28]

Table 3. **List of Selected Recently Commissioned Small Hydropower Plants in Ukraine**

Name	*Location*	*Capacity (MW)*	*Head*	*Plant type*	*Operator*	*Launch year*
Brusturyanka	Brusturyanka River, Lopukhovo	1.00	16.5	Diversion, run-of-river	"RENER" Group	2016
Janowiec	Janowiec River, Rus'ka Mokra	0.99	86.21	Diversion, run-of-river	"RENER" Group	2017
Brusturyanka 2	Brusturyanka River, Ust-Chorna	0.99	16.15	Diversion, run-of-river	"RENER" Group	2018
Kapustyanska	Kapustyanska Stream, Zaporizhzhia	0.48	32.00	Storage, run-of-river	LTD "HIDROPAUER-1"	2018
Poltava Hidro	Poltava region, Horbanivka	0.19	36.00	Diversion, run-of-river	LTD "POLTAVA HIDRO"	2018
Velyka Bahachka	Psel River, Velyka Bahachka	0.45	3.40	Storage, run-of-river	LTD "HIDROENERHO-RESURS"	2019
Tetiivska	Roska River, Tetiiv	0.13	3.00	Storage, run-of-river	LTD "HIDROENERHO-RESURS"	2019

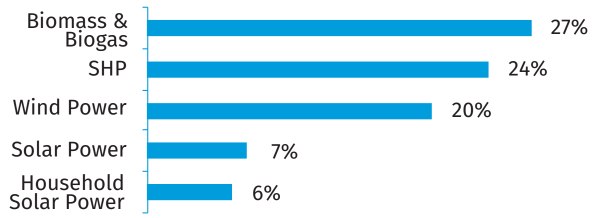
Name	*Location*	*Capacity (MW)*	*Head*	*Plant type*	*Operator*	*Launch year*
Ispaska	Cheremosh River, Ispas	0.20	3.50	Diversion, run-of-river	LTD "ENERHOINVEST"	2019
Velyko Yablunivska	Tyasmin River, Velyka Yablunivka	0.08	3.00	Storage, run-of-river	LTD "ZHK"	2019
Salkivska	Southern Buh River, Salkove	0.20		Storage, run-of-river	IE "BOYKO YE.L."	2019
Velykohayivska	Hnizna River, Dychkiv	0.15	4.10	Storage, run-of-river	LTD "OS-NOVA"	1952/ 2019
Lyuks 2	Seret River, Myshkovychi	0.08	3.00	Storage, run-of-river	PSE "LYUKS"	2019
Rener 1	Malyi Stream, Kostylivka	1.00		Diversion, run-of-river	LTD "RENER"	2019
Rener 2	Velykyi Stream, Kostylivka	1.00		Diversion, run-of-river	LTD "RENER"	2019
Orlove	Yatran River, Orlove	0.18	3.00	Storage, run-of-river	LTD "HIDROENERHOINVEST"	2019
Pylypchanska	Ros River, Pylypcha	0.93	3.00	Storage, run-of-river	LTD "HIDRO-INVEST"	2019
Doroshivska	Murafa River, Doroshivka	0.09		Storage, run-of-river	LTD "NYU ENERDZHY"	2019
Velyka Liubashivska	Zamchisko River, Velyka Liubasha	0.08	2.80	Storage, run-of-river	PJSC "RIVNEVTORMET"	2019
Matyushivska	Rostavytsia River, Matiushi	0.10	4.30	Storage, run-of-river	LTD "UKRBIOPROMPOSTACH"	2019
Slavutska	Goryn River, Slavuta	0.20		Storage, run-of-river	LTD "SLAVHIDRO"	2019

Source: Energo.ua,[18] Stefanyshyn,[24] RENER Group[25]

According to the National Renewable Energy Action Plan of Ukraine for the period until 2020, it was planned to achieve an increase in SHP capacity of up to 150 MW by 2020 through the modernization of existing facilities, the restoration of old SHP plants and the construction and commissioning of new ones.[29] That estimate was not as large as a previous estimate of 1–2 GW earlier considered by UkrHydroProject (UHP), the largest engineering company in the field of hydropower and hydraulic construction in Ukraine.[26,30] In turn, according to the first version of the Energy Strategy of Ukraine for the period until 2030, the SHP potential capacity of Ukraine was estimated at 1,140 MW (as mentioned in the *WSHPDR 2019*).[15,3] However, these estimates may have been based on the old definition of SHP and included projects up to 30 MW.[3,15,30] The recent results of a market assessment of SHP rehabilitation in Ukraine by the World Bank indicated a total feasible technical potential for SHP development in Ukraine (including currently installed capacity) of approximately 280 MW.[26]

In 2019, 157 SHP plants, with a total installed capacity of 114 MW, generated 242 GWh of electricity in Ukraine. The share of SHP plants in the non-traditional renewable energy mix (including solar power, wind power and biomass) was 4.1 per cent. The installed capacity utilization rate of SHP was 24 per cent in 2019 (Figure 6).[31]

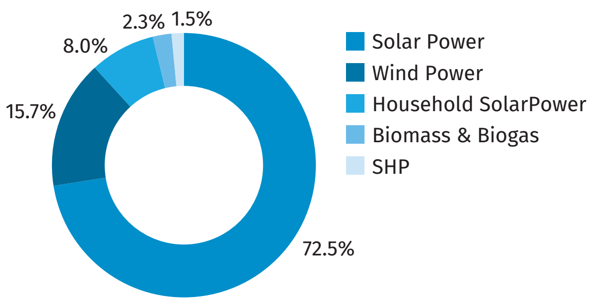
Figure 6. **Installed Capacity Utilization Rate of Renewable Energy Operating under the FIT in Ukraine in 2019**



Source: SAEE[31]

The share of SHP installed capacity in the IPS of Ukraine is marginal compared to other renewable sources (Figure 7).[30] Between 2010 and the first quarter of 2020, there was a significant reduction in the share of SHP in non-traditional renewable energy installed capacity mix — from 43.0 per cent to 1.5 per cent.[13] This was a result of the growing capacities of other renewable sources, in particular solar power.[32]

Figure 7. **Share of Non-traditional Renewable Energy Sources in the Installed Capacity of Ukraine in 2020 (%)**



Source: SAEE[32]

Note: Excluding the temporary occupied and uncontrolled territories.

Between 2013 and 2019, the installed capacity utilization rate of SHP plants operating under the FIT in Ukraine decreased from approximately 44 per cent to 24 per cent. Such a decrease is explained first of all by the reduction of water discharge in the rivers on the territory of Ukraine, which occurred during that period. Secondly, it might have been a result of the insufficient substantiation of new projects, in particular, due to the overestimation of feasible hydropower potential.[33] There was also a 25 per cent reduction in the cost of electricity production by SHP plants for the period of 2012–2019. However, this was the lowest reduction in production cost among all types of renewable energy in Ukraine, which is likely explained by the significant difficulties in obtaining building permits relative to other renewable energy plants.[34,35] Besides, given the poor condition of the infrastructure of older SHP plants, the low hydropower potential of Ukrainian rivers and the FIT rates, many Ukrainian entrepreneurs focus on developing only the smallest SHP plants with a capacity of up to 200 kW.[18,34] Several ongoing and planned SHP projects are displayed in Table 4.[36]

Table 4. **List of Selected Ongoing and Planned Small Hydropower Projects in Ukraine**

Name	*Location*	*Capacity (MW)*	*Head*	*Plant type*	*Operator*	*Planned launch year*	*Development stage*
Dobrotvirska	Western Buh River, Stary Dobrotvir	1.00	7.8	Storage, diversion, run-of-river	LLC "AKVARESURS-2"	2021–2022	Ongoing
Ternivska	Sinyukha River, Ternivka	0.20	2.0	Storage, run-of-river	PE "BENCHYK MLYN"	2021–2022	Planned
Kurchytska	Sluch River, Kurchytsya	0.20	2.5	Storage, run-of-river	"WATERSTRUM" LLC	2021–2022	Planned
Vygodska	Svicha River, Vygoda	0.40	5.0	Storage, diversion, run-of-river	"EKOENERHETYKA" LLC	2021–2022	Planned
Stril'chyntska	Southern Buh River, Stril'chyntsi	0.20	6.0	Storage, diversion, run-of-river	"AGROGES" LLC	2021–2022	Planned

Source: Stefanyshyn,[24] Ministry of Environmental Protection and Natural Resources[36]

One prospective area for SHP development is installation of SHP facilities on existing man-made infrastructure, such as drainage and irrigation canals, outflow pipes of non-powered dams and wastewater runoff pipes. Two such pilot projects have already been implemented at wastewater treatment facilities in Ukraine. The first one, implemented in 2018 at the Suprunivska sewage treatment plant in Poltava, has a capacity of 190 kW and generates up to 1.24 GWh per year. The second pilot SHP plant was also implemented in 2018 on the Kapustyansky reservoir in the city of Zaporizhzhia, with a capacity of 484 kW and generates up to 2.1 GWh of electricity per year.[18,24]

RENEWABLE ENERGY POLICY

Renewable energy sources including SHP are eligible to benefit from the FIT in Ukraine.[16] The application of FITs to renewable energy sources, improvement of the energy efficiency of large combustion plants (thermal power and cogeneration plants) and encouragement of the implementation of low-carbon technologies are considered the main components of the policy on climate change in Ukraine.[3,16,37] However, in 2019, there were some changes in Ukrainian legislation on FITs for renewable energy sources. On 25 April 2019, the Verkhovna Rada of Ukraine adopted the Law On Amendments to Certain Laws of Ukraine on Ensuring Competitive Conditions for Electricity Production from Renewable Energy Sources.[38] The law introduced a new support scheme for renewable energy, a reduction of the FIT and a procedure for conducting green auctions to identify business entities eligible for support, including compensation for participation in such auctions.[16] The passage of this new law was deemed necessary because the previously-established FIT for green electricity was believed to be excessively high, in particular for solar power plants, leading to an excessive price burden for Ukrainian electricity consumers, which would only increase as new power plants are commissioned.[16] The law was subsequently superseded by the Memorandum of Understanding on the Settlement of Problematic Issues of the Ukrainian Renewable Energy Sector, signed into law on 10 June 2020.[39] According to the Law on Amendments, the existing FIT scheme (Table 5) is guaranteed until 2030; however, with regard to the FIT rates for various renewable energy sources, the more recent Memorandum of Understanding provides for several tariff reductions, as displayed in Table 6.[38]

In 2020, due to the economic crisis in the country, tariffs for electricity produced at facilities using alternative energy sources were reviewed quarterly by the NEURC. Tariffs were established individually for electricity producers, taking into account the surcharge for compliance with the level of use of Ukrainian-made equipment. Currently, NEURC resolution No. 2877 of 31 December 2020 is valid, with tariffs for producers ranging between UAH 1.994 and UAH 8.408 (USD 0.072–0.300) per kWh.[23] However, the minimum FITs for SHP, based on the installed capacity, are maintained at the previous level (Table 5).[18,23,38]

Maintaining its focus on energy-saving technologies and renewable energy, the Energy Efficiency Agency of Ukraine is planning to implement a market for green bonds in order to stimulate interest in renewable energy development. This initiative will involve the development of a package of primary and secondary draft laws that will provide the guidelines for green bonds, reducing barriers to an otherwise encouraging green investment in Ukraine.[16] With regard to SHP specifically, in December 2020 NEURC renewed the green tariffs for electricity produced using SHP by various economic entities, taking into account the capacity of installations and surcharges for the use of Ukrainian-produced equipment.[18,23] These tariffs vary from 0.1045 EUR/kWh (0.13 USD/kWh) to 0.1939 EUR/kWh (0.23 USD/kWh) (excluding VAT) (Table 7).[18,23]

Table 5. **Minimum FITs for Renewable Energy Producers (2018)**

Renewable energy source	*Category/installed capacity*	*Minimum FIT (EUR/kWh (USD/kWh), exclusive of VAT) for power plants by commissioning date*		
		1 Jan 2017 – 31 Dec 2019	*1 Jan 2020 – 31 Dec 2024*	*1 Jan 2025 -- 31 Dec 2029*
Wind power	≤ 600 kW	0.058 (0.07)	0.052 (0.06)	0.045 (0.05)
	600–2,000 kW	0.068 (0.08)	0.060 (0.07)	0.053 (0.06)
	> 2,000 kW	0.102 (0.12)	0.091 (0.11)	0.079 (0.10)
Biomass/biogas		0.124 (0.15)	0.112 (0.13)	0.099 (0.12)
Solar power	Ground-mounted	0.150 (0.18)	0.135 (0.16)	0.120 (0.14)
	Roof-mounted	0.164 (0.20)	0.148 (0.18)	0.131 (0.16)
Hydropower	Micro-hydropower (< 200 kW)	0.175 (0.21)	0.157 (0.19)	0.140 (0.17)
	Mini-hydropower (200–1,000 kW)	0.140 (0.17)	0.126 (0.15)	0.112 (0.13)
	Small hydropower (1–10 MW)	0.105 (0.13)	0.091 (0.11)	0.084 (0.10)
Geothermal power		0.150 (0.18)	0.135 (0.16)	0.120 (0.14)

Source: Vovchak et al.[40]

Table 6. **Amendments to FITs**

Commissioning date	*FIT reduction*		
01 Jul 2015 – 31 Dec 2019	Solar power ≥ 1 MW	Solar power < 1 MW	Wind power
	15%	10%	7.5%*
From 1 Jan 2020	2.5% (irrespective of installed capacity)		
Before 01 Jul 2015	The FIT is capped at the level of the FIT for ground solar installations of > 10 MW commissioned before 31 Mar 2013, decreased by 15%		

Source: Teush, S.[39]

Note: *except where the installed unit capacity of a wind turbine is less than 2 MW.

Additional incentives available to investors and producers of renewable energy include exemptions from VAT and customs duties for imports of raw and processed materials, components and equipment that will be used in the generation of renewable energy.[3]

Table 7. **Distribution of FIT Rates for Small Hydropower in Ukraine (2021)**

FIT rate (EUR/kWh (USD/kWh))	*SHP plants*	
	Number	*Share (%)*
0.1045 (0.13)	4	2.4
0.1163 (0.14)	71	42.5
0.1395 (0.17)	18	10.8
0.1551 (0.19)	8	4.8
0.1700 (0.20)	3	1.8
0.1745 (0.21)	44	26.3
0.1939 (0.23)	19	11.4
Total	**167**	**100.0**

Source: Energo.ua[18]

In general, the national renewable energy policy and environmental regulations in the country have not changed since the release of the *WSHPDR 2019*.[3] Recent developments include the work on the practical implementation of The Law of Ukraine On Environmental Impact Assessment (EIA) and the adoption of The Law of Ukraine On Strategic Environmental Assessment (SEA).[41,42] All current changes in the country's renewable energy policy and the protection, conservation and use of natural resources take into account current EU acquis and/or international agreements, in particular, the EU Renewable Energy Directive, the Environmental Impact Assessment Directive, the Strategic Environmental Assessment Directive, the Water Framework Directive, the Paris Agreement on climate change as well as the Aarhus, Espoo and Berne Conventions.

In addition, the Government of Ukraine has started the process of developing a National Framework Strategy for Adaptation to Climate Change. In November 2020, the first meeting of the Climate Change Adaptation Working Group was held to discuss the country's strategy for adaptation to climate change, the climate risks threatening the economy and how to integrate the experience of other cities and ecosystems into the national climate change adaptation strategy.[43] The Government of Ukraine will be supported in this process by the EU project EU4Climate, which is being implemented by the United Nations Development Programme (UNDP) in Ukraine.[43,44]

SMALL HYDROPOWER LEGISLATION AND REGULATIONS

At the moment, there are no Government plans or programmes specifically targeting SHP in Ukraine. In general, design, construction and reconstruction of hydraulic and other SHP structures must be carried out in accordance with the current building codes.[45] In addition to the general legal aspects pertaining to SHP planning, construction, operation as well as distribution, environmental and water legislation applies.[16] The Water Code of Ukraine provides regulations governing the planning, construction and operation of all hydropower plants regardless of the scale.[46] This Code specifies regulations pertaining to land allocation as well as obtaining authorization for operating facilities that use water resources.[3,16,46] Furthermore, it is necessary to comply with the Law on EIA.[41] The law establishes legal and organizational principles for EIA to be carried out for all hydropower plants regardless of installed capacity. The Law on EIA incorporates the European model of EIA and significantly expands the range of facilities that are subject to assessment. Additionally, in comparison with the earlier Law on Ecological Expertise, the EIA procedure itself has become more extensive.[16]

Regardless of the existing legal and regulatory framework, there are still many examples of non-compliance with existing building codes, violations of the Water Code's requirements as well as the requirements of the Law on EIA and the Law on SEA. [41,42,45,46] Violations are committed by both developers and regulatory agencies.[47] It should be noted that in Ukraine, hydropower development carries significant environmental and water risks because of the scarcity of water resources.[33,48] Therefore, compliance with environmental requirements can be considered as one of the main conditions for the planning, construction, distribution and operation of SHP plants in Ukraine.

One primary issue with the construction of new SHP plants, especially on mountain rivers, is disturbance of the natural state of the rivers' ecosystems.[16] Numerous examples of damage to river ecosystems caused by both rehabilitated SHP plants on rivers in the plain region of Ukraine (including the Southern Bug, Sluch, Ros and Seret) and by new SHP plants built recently on the small rivers in the Ukrainian Carpathians (the Krasna, Rika and Shypit) have been recorded.[48] For example, in 2017 the Chizhivska SHP plant near the city of Novograd-Volinskiy was implicated in the extreme decline of water levels in the Sluch River, requiring the temporary suspension of the plant's operation and a subsequent resumption of operation at reduced levels of water consumption.[49] The World Wildlife Fund (WWF) in Ukraine has repeatedly emphasized that the uncontrolled construction of SHP plants in the country can lead to the extinction of unique fish species and other aquatic organisms, deterioration of river water quality and changes in the rivers' hydro-morphological regimes, drainage and other characteristics. These impacts can also lead to increased social tensions and second-order environmental damage.[50] Although investors are keen to promote SHP as an environmentally-friendly alternative to large hydropower and other energy sources, in the Ukrainian context, it is not clear whether the impact of SHP plants on the environment is necessarily less than that of large hydropower plants relative to the energy produced, particularly in the case of reservoir-type SHP plants.[12,13,48,51]

EFFECTS OF CLIMATE CRISIS ON SMALL HYDROPOWER DEVELOPMENT

Climate change is a potentially significant threat to the Ukrainian economy, in particular to its strategically important and growing agricultural sector. Current climate change trends, if they continue, could lead to 70 per cent of Ukrainian agricultural lands requiring additional irrigation, increasing the total irrigation requirement by over a third of what it is today. Additionally, parts of southern Ukraine are now at risk of desertification.[4] The water shortage issue may also be a critical one for the country's hydropower sector.[48] Current hydrological studies show that climate change has been affecting the water regime of rivers flowing within Ukraine. By the middle of the 21st century, reduction of essential water resources is expected on the plains territory of Ukraine, where the majority of the operating hydropower plants and SHP plants are situated.[18,52] Because of a reduction of river runoff, particularly during the low-flow period, water use by existing hydropower plants on the Dnipro, Dniester, Southern Bug, Sluch and other rivers is already being restricted by limits.[44] In turn, adaptation measures to ensure a sustainable use of hydropower might require additional river runoff regulation in order to avoid affecting the environment and reducing access to water resources for other water users.[48]

BARRIERS AND ENABLERS FOR SMALL HYDROPOWER DEVELOPMENT

Overall, the current regulatory framework of Ukraine provides good opportunities for the development of SHP in the country. At the same time, environmental problems associated with SHP plants could continue to be a significant challenge in the future if not properly addressed.

The main barriers to SHP development in Ukraine can thus be summarized as being two-fold:

- Poor reputation of SHP among some communities and environmentalists due to environmental issues caused by previous unsuccessful SHP projects. The failure of these projects can be attributed to insufficiently comprehensive EIAs that did not properly analyse and map out alternative options and implement appropriate compensatory measures;
- The country's relatively poor natural hydropower potential, one of the lowest in the world in the case of local rivers. Small and medium-sized rivers flowing through the territory of Ukraine show a relatively low and uneven runoff (up to 70 per cent or more of their annual runoff occurs during short periods of floods). In addition, most rivers where SHP plants are situated flow on the plains, with relatively small height difference from source to mouth. For example, for rivers of the Dnieper basin, it does not exceed 50–70 metres, and in the Southern Bug basin is approximately 100–150 metres. In the Carpathians, rivers have a slightly greater overall height difference downstream, of approximately 300–400 metres.[33,35,47,48,49,50]

One potential enabler for SHP development in Ukraine is the so-called hidden hydropower potential, namely, relating to the outflow of non-powered dams, municipal and industrial reservoirs and ponds, sewage and wastewater treatment runoff pipes and other man-made infrastructure for the distribution of water for agricultural or other purposes. This hidden hydropower potential has not yet been thoroughly studied, but could boost the implementation of successful SHP projects while reducing the potential of adverse environmental impacts.[35]

Ukraine needs both national and regional programmes on SHP development. These programmes should be developed with the involvement of all stakeholders including scientists, local communities and non-governmental organizations to ensure the coordination of different concerns, the making of knowledge-based decisions and the finding of feasible trade-offs. The programmes should be also adopted taking into account the requirements of the Law of Ukraine on SEA, making it possible to determine no-go areas for hydropower development and also unlocking the hidden hydropower potential described above.[42]

REFERENCES

1. World Bank (n.d.). *Ukraine*. The World Bank. Data. Available at https://data.worldbank.org/country/UA (Accessed 1 January 2020).
2. Encyclopaedia Britannica (n.d.). *Ukraine*. Available at https://www.britannica.com/place/Ukraine (Accessed 1 January 2020).
3. 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.
4. Ackermann, A. (2020). *Climate change threatens the Ukrainian breadbasket*. Atlantic Council. Available at https://www.atlanticcouncil.org/blogs/ukrainealert/climate-change-threatens-the-ukrainian-breadbasket/ (Accessed 1 January 2020).
5. Food and Agriculture Organization (FAO) (n.d.). *Ukraine. Water resources*. FAO of the United Nations. Available at http://www.fao.org/NR/water/aquastat/countries_regions/Profile_segments/UKR-WR_eng.stm (Accessed 03 April 2021).
6. Khilchevskyi, V.K., Grebin, V.V. & Sherstyuk, N.P. (2019). *Modern hydrographic and water management zoning of Ukraine's territory – implementation of the WFD-2000/60/EC*. Proceedings of the XXVII Conference of the Danubian Countries on Hydrological Forecasting and Hydrological Bases of Water Management, Kyiv, Ukraine, November 6-8, 2019, 209-223 https://doi.org/10.15407/uhmi.conference.01.23.
7. Khilchevskyi, V., Grebin, V., Zabokrytska, M., Zhovnir, V., Bolbot, H. & Plichko, L. (2020). Hydrographic characteristic of ponds distribution in Ukraine – Basin and regional features. *Journal of Water and Land Development.* No. 46 (VII–IX) p. 140–145. DOI: 10.24425/jwld.2020.134206.
8. Ukrernergo (2020). *Installed capacity of the IPS of Ukraine values as of 11/2020*. Available at https://ua.energy/installed-capacity-of-the-ips-of-ukraine/ (Accessed 03 April 2021).
9. Ukrernergo (2019). *New horizons. Non-financial report*. Available at https://ua.energy/wp-content/uploads/2020/09/NeFIN_ZVIT_17.09.20.pdf (Accessed 03 April 2021).
10. International Energy Agency (IEA) (2020). *Ukraine energy profile*. Country report – April 2020. IEA. Available at https://www.iea.org/reports/ukraine-energy-profile (Accessed 03 April 2021).
11. Verkhovna Rada of Ukraine (2016). *Hydropower development programme for the period until 2026*. Approved by the order of the Cabinet of Ministers of Ukraine from 13.07. 2016 № 552-r. Available at http://zakon2.rada.gov.ua/laws/show/552-2016-%D1%80#n7 (Accessed 03 April 2021).
12. Stefanyshyn, D.V. (2019). Feasibility analysis of construction of new hydropower plants in Ukraine taking into account the risk of unused possibilities. *Environmental Safety and Natural Resources*, 31(3), 33–45. DOI: 10.32347/2411-4049.2019.3.33-45.
13. Stefanyshyn, D.V. & Vlasiuk, Yu.S. (2020). *On the feasibility of the development of small hydropower in Ukraine*. 3nd International Scientific and Technical Internet Conference "Innovative development of resource-saving technologies and sustainable use of natural resources". Book of Abstracts. Petroșani, Romania: Universitas Publishing, 57-60.
14. World Bank (n.d.). *Access to electricity (% of the population) - Ukraine*. The World Bank. Data. Available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=UA (Accessed 03 April 2021).
15. Verkhovna Rada of Ukraine (2017). *On approval of the Energy Strategy of Ukraine for the period until 2035 "Safety, Energy efficiency, Competitiveness"*. Order of the Cabinet of Ministers of August 18, 2017, № 605-r. Available at https://zakon.rada.gov.ua/laws/show/605-2017-%D1%80?lang=en#Text (Accessed 03 April 2021).
16. DLF Attorneys-at-Law (2019). *Renewable energy in Ukraine Q&A*. Available at https://dlf.ua/en/renewable-energy-in-ukraine-q-a/ (Accessed 03 April 2021).
17. Organization for Economic Co-operation and Development (OECD) (2019). *Snapshot of Ukraine's Energy Sector: Institutions, Governance and Policy Framework*. Available at https://www.oecd.org/eurasia/competitiveness-programme/eastern-partners/Snapshot-of-Ukraines-Energy-Sector-EN.pdf (Accessed 03 April 2021).
18. Energo.ua (n.d.). *Renewable assets*. Available at https://www.energo.ua/en/assets (Accessed 03 April 2021).
19. Verkhovna Rada of Ukraine (2017). *The Law of Ukraine "On Electricity" (with amendments as of June 11, 2017)*. Available at http://zakon.rada.gov.ua/laws/show/575/97-%D0%B2%D1%80 (Accessed 03 April 2021).
20. Minfin.com.ua (n.d.). *Electricity tariffs in 2021*. Available at https://index.minfin.com.ua/tariff/electric/ (Accessed 03 April 2021).
21. Minfin.com.ua (n.d.). *Electricity distribution tariffs for companies*. Available at https://index.minfin.com.ua/tariff/electric/prom/ (Accessed 03 April 2021).
22. Epravda.com.ua (2018). *Media sources: Oblenergo planning*

a tariff hike due to RAB-tariffs. Available at https://www.epravda.com.ua/rus/news/2018/02/15/634112/ (Accessed 03 April 2021).

23. National Energy and Utilities Regulatory Commission (NEURC) (2020). *Decree 31.12.2020 # 2877: About establishment of "green" tariffs for the electric power and a surcharge to "green" tariffs for observance of a level of use of the equipment of the Ukrainian production for business entities*. Available at https://nerc.gov.ua/?id=58069 (Accessed 03 April 2021).
24. Stefanyshyn, D. (2021). Personal research and communication with stakeholders (unpublished).
25. RENER Group (n.d.). *Hydroelectric energy.* Available at http://rener.com.ua/hydrostation (Accessed 24 April 2021).
26. World Bank (2019). *The Executive Summary - Market assessment of Small Hydropower Plants in Ukraine.* P161875. World Bank Document. Public Disclosure Authorized. Available at http://documents1.worldbank.org/curated/en/472871561153957631/pdf/The-Executive-Summary-Market-Assessment-of-Small-Hydro-Power-Plants-in-Ukraine.pdf (Accessed 03 April 2021).
27. 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.
28. 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.
29. Energy Community (n.d.). *National Renewable Energy Action Plan for the period until 2020*. Approved by the Cabinet of Ministers of Ukraine Executive Order No. 902-p of 1 October 2014. Available at https://www.energy-community.org/implementation/Ukraine/reporting.html (Accessed 04 April 2021).
30. Landau, Yu. A. (2012). The main trends in the development of hydropower in Ukraine. *Technogenic safety.* Vol. 53. Issue 40, 82-86.
31. State Agency on Energy Efficiency and Energy Saving of Ukraine (SAEE) (2020). *Statistical information as of 1 January 2020.* Available at https://saee.gov.ua/sites/default/files/VDE_2019.pdf (Accessed 04 April 2021).
32. State Agency on Energy Efficiency and Energy Saving of Ukraine (SAEE) (2020). *Statistical information as of 1 April 2020.* Available at https://saee.gov.ua/sites/default/files/1_kv_2020_VDE.pdf (Accessed 04 April 2021).
33. Stefanyshyn, D. V. (2018). On peculiarities of hydropower development in the world and in Ukraine. *Environmental safety and natural resources*. Issue 25 (1), 12-23. DOI: 10.32347/2411-4049.2018.1.12-23
34. Bielawski, M. (2020). *Signposts for the development of alternative energy in Ukraine until 2030*. Razumkov Center. Articles and interviews. Available at https://razumkov.org.ua/statti/oriientyry-rozvytku-alternatyvnoi-energetyky-ukrainy-do-2030r (Accessed 04 April 2021).
35. World Wildlife Fund (WWF) Ukraine (2019). *The lack of environmental standards in small hydropower poses a threat to Ukrainian rivers*. Available at https://wwf.ua/?uNewsID=354457 (Accessed 04 April 2021).
36. Ministry of Environmental Protection and Natural Resources (n.d.). *Single registry of environmental impact assessments.* Available at http://eia.menr.gov.ua/uk/cases (Accessed 24 April 2021).
37. Food and Agriculture Organization (FAO) (2017). *Ukraine 2050 Low Emission Development Strategy*. FAOLEX Database. FAO of the United Nations. Available at http://extwprlegs1.fao.org/docs/pdf/ukr181201.pdf (Accessed 04 April 2021).
38. Verkhovna Rada of Ukraine (2019). *The Law of Ukraine "On Amendments to Certain Laws of Ukraine on Ensuring Competitive Conditions for Electricity Production from Renewable Energy Sources".* Available at https://zakon.rada.gov.ua/laws/show/2712-19?lang=en#Text (Accessed 04 April 2021).
39. Teush, S. (2020, 17 June). *Ukraine: the memorandum on the reduction of the feed-in tariff signed by the government and renewable energy industry associations.* Redcliffe Partners. Available at https://www.mondaq.com/renewables/954248/the-memorandum-on-the-reduction-of-the-feed-in-tariff-signed-by-the-government-and-renewable-energy-industry-associations (Accessed 24 April 2021).
40. Vovchak, V., Teslenko, O., Samchenko, O., & Ermilov, S. (ed.) (2018). *Small hydropower in Ukraine. Vol. 1: Analytical overview*. Institute of Problems of Ecology and Energy Efficiency (IPEE). Kiev, 2018. Available at http://energyukraine.org/wp-content/uploads/2018/05/Otchet-MGES1.pdf (Accessed 04 April 2021).
41. Verkhovna Rada of Ukraine (2020). *The Law of Ukraine "On Environmental Impact Assessment" No.2059-VIII of May 23, 2017*. (Revision on December 1, 2020). Available at https://zakon.rada.gov.ua/laws/show/2059-19?lang=en#Text (Accessed 04 April 2021).
42. Verkhovna Rada of Ukraine (2020). *The Law of Ukraine "On Strategic Environmental Assessment" No. 2354-VIII of March 20, 2018*. (Revision on January 1, 2020). Available at https://zakon.rada.gov.ua/laws/show/2354-19?lang=en#Text (Accessed 04 April 2021).
43. United Nations Development Programme in Ukraine (UNDP Ukraine) (2020). *UNDP, EU support Ukrainian government in development of National Adaptation Strategy*. Available at https://www.ua.undp.org/content/ukraine/en/home/presscenter/pressreleases/2020/undp--eu-support-ukrainian-government-in-development-of-national.html (Accessed 04 April 2021).
44. EU4Climate (n.d.). *Ukraine*. Available at https://eu4climate.eu/ukraine/ (Accessed 04 April 2021).
45. State Building Standards of Ukraine (DBN) (2010). *DBN B.2.4-3: Hydrotechnical, energy and reclamation systems and structures, underground mining. Waterworks. Substantive provisions.* State Building Standards of Ukraine, Kyiv, Ministry of Regional Development and Construction of Ukraine, 2010. Available at https://dbn.co.ua/load/normativy/dbn/1-1-0-802 (Accessed 04 April 2021).
46. Verkhovna Rada of Ukraine (2020). *The Water Code of Ukraine (Revision on October 16, 2020)*. Available at http://

zakon2.rada.gov.ua/laws/show/213/95-%D0%B2%D1%80 (Accessed 04 April 2021).

47. Stefanyshyn, D.V. & Vlasiuk, Yu.S. (2019). Some critical comments on the quality of environmental impact assessment reports for small hydropower plants in Ukraine. *Environmental Safety and Natural Resources*, 32 (4), 43-59. DOI: 10.32347/2411-4049.2019.4.43-59.
48. Adamenko, T.I., Demydenko, A.O., Romashchenko, M.I., Tsvietkova, A.M., Shevchenko, A.M. & Yatsyuk, M.V. (2016). *Rethinking of Water Security for Ukraine based on results of National Policy Dialogue*. GWP-Ukraine and UNENGO "MAMA-86". Available at https://www.gwp.org/globalassets/global/gwp-cee_files/regional/rethinking-water-security-ukraine-2016.pdf (Accessed 04 April 2021).
49. Stefanyshyn, D. V. & Vlasiuk, Y. S. (2019). On some challenges of environmental impact assessment of small hydropower plants in Ukraine. *Environmental Safety and Natural Resources*, 31(3), 79-92. Available at https://www.researchgate.net/profile/Dmytro_Stefanyshyn2/publication/337128623_On_some_challenges_of_environmental_impact_assessment_of_small_hydropower_plants_in_Ukraine/links/5df7c424a6fdcc2837268907/On-some-challenges-of-environmental-impact-assessment-of-small-hydropower-plants-in-Ukraine.pdf (Accessed 04 April 2021).
50. World Wildlife Fund (WWF) (2018). *WWF position paper on small hydropower development in Ukraine*. Available at https://energyukraine.org/wp-content/uploads/2018/05/position-SHPPs-eng.pdf (Accessed 04 April 2021).
51. Stefanyshyn, D. V. & Vlasiuk, Y. S. (2018). On the question of comparative analysis of water energy characteristics of small and large hydroelectric power plants in Ukraine consisting of hydroelectric facilities with reservoirs. *Mathematical modelling in the economy* (2), 71-83. Available at: http://irbis-nbuv.gov.ua/cgi-bin/irbis_nbuv/cgiirbis_64.exe?C21COM=2&I21DBN=UJRN&P21DBN=UJRN&IMAGE_FILE_DOWNLOAD=1&Image_file_name=PDF/mmve_2018_2_8.pdf (Accessed 04 April 2021).
52. Loboda, N. & Bozhok, Y. (2016). Water resources of Ukraine in the XXI century under climate change scenarios (RCP4.5 AND RCP8.5). *Ukrainian Hydrometeorological Journal*, (17), 114-122. Available at https://doi.org/10.31481/uhmj.17.2016.13 (Accessed 04 April 2021).

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 UTP 1981

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

SGP The GEF Small Grants Programme
DOMINICAN REPUBLIC

gef

UN DP

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

M C M X X I I
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