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World Small Hydropower Development Report 2019

Europe

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World Small Hydropower Development Report 2019

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4.1 Eastern Europe

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Introduction to the region

The region of Eastern Europe comprises ten countries, all of which are former Eastern Bloc members or Soviet republics. While Bulgaria, the Czech Republic, Hungary, Poland, Romania and Slovakia are members of the European Union, integrated into its structures and legislation system, the situation of the former Soviet republics – the Russian Federation, Belarus, the Republic of Moldova and Ukraine – remains highly diverse. An overview of the countries of the region is given in Table 1.

Apart from the Russian Federation, the climate in the region may be described as mild with features of a transitional climate in Poland and a continental climate in Belarus and Ukraine. A Mediterranean-like climate prevails at large portions of the Black Sea coast. Moderate precipitation of approximately 600 mm/year is typical for the region, although it can substantially exceed 1,000 mm/year in mountain ranges and fall below 400 mm/year in some areas of the Central and East European Plain. The climate of the European part of Russia varies from sub-Mediterranean at the Black Sea coast, through continental at dry steppes of the Caspian region and most of the East European Plain to subarctic in the Far North.

There is a high variation of hydropower potential density in the region. The best conditions are encountered in Russia, Romania and Bulgaria. Significant untapped technical potential still exists in Ukraine. With 48 GW of installed hydropower capacity, the Russian Federation uses merely 10.8 per cent of its vast technical hydropower potential.[10]

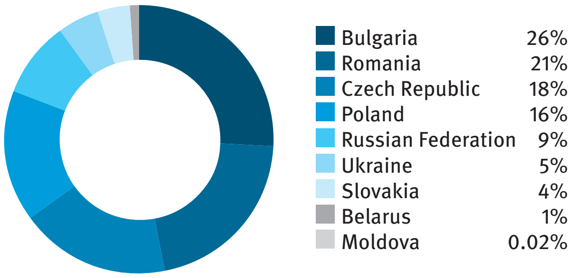
A feature distinguishing the Russian and Ukrainian hydropower sectors from most other countries in the region is large hydroelectric schemes erected at large rivers, which heavily prevail over SHP installations. The ambitious Ukrainian pumped storage projects have slowed down recently due to the prolonged economic and political crisis.

The regional electrification rate is 100 per cent. The electrical power network is dominated by thermal power plants. The nuclear sector also plays an important role in the region, with the main nuclear power contributors being Russia and Ukraine. The nuclear sector is the main source of electricity in Bulgaria, Hungary and Slovakia, whereas natural gas plants provide over 90 per cent of the electricity generated in Belarus. Fossil fuels (coal and lignite) remain the main energy carriers in Poland, still contributing over 81 per cent of the national electricity generation.

Hydropower contributes 13 per cent of electricity generation in the region (Table 1). The double-digit hydropower contribution to generated electricity is also a characteristic feature of the electricity mixes of Romania (23.3 per cent), the Russian Federation (17.0 per cent) and Slovakia (16.7 per cent). The lowest hydropower contribution (below 2 per cent) to the national electricity mix in terms of generation can be observed in Belarus (0.1 per cent), Hungary (0.8 per cent) and Poland (1.5 per cent). Since the *World Small Hydropower Development Report (WSHPDR) 2013*, the region has shown a growth of 5,167 MW, or 8 per cent, in hydropower installed capacity. The main contributors have been Bulgaria, the Russian Federation and Ukraine.

In most countries within the region, small hydropower (SHP) has been wholly responsible for the growth in hydropower sectors which has taken place since the *WSHPDR 2016*. The regional leaders in SHP (up to 10 MW) installed capacity are Bulgaria (26 per cent), Romania (21 per cent), the Czech Republic (18 per cent) and Poland (16 per cent) (Figure 1). Using the 10 MW SHP limit instead of 30 MW, which was the case in the previous report, shifts the Russian Federation to the fifth position.

Figure 1.
Share of regional installed capacity of small hydropower up to 10 MW by country in Eastern Europe (%)



Source: *WSHPDR 2019*[3]

Note: Does not include Hungary as data on capacity up to 10 MW is not available.

Table 1.
Overview of countries in Eastern Europe

Country	*Total population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Belarus	9.5	22	100	10,069	34,515	95	405
Bulgaria	7.1	25	100	12,070	40,684	3,204	3,395
Czech Republic	10.6	26	100	21,989	83,300	1,090	2,001
Hungary	9.8	29	100	8,479	31,859	57	259
Moldova	3.6	57	100	3,001	5,108	64	226
Poland	38.4	40	100	41,396	162,626	988	2,399
Romania	19.9	46	100	23,738	61,300	6,389	14,300
Russian Federation	146.8	26	100	239,812	1,053,862	48,450	178,902
Slovakia	5.4	46	100	7,721	28,030	2,539	4,677
Ukraine	45.0	31	100	55,330	154,820	6,220*	9,120*
Total	**296.1**	-	-	**423,605**	**1,656,104**	**69,096**	**215,684**

Source: *WSHPDR 2019*,[3] WB,[4] WB,[5] Belstat,[6] ANRE,[7] UES System Operator,[8] ERO[9]

Note: * Including pumped storage hydropower.

Small hydropower definition

Most countries within the region use the 10 MW threshold for SHP (Table 2). The limit of 5 MW is used in Hungary, and 1 MW in Bulgaria. Poland has no official definition, however, hydropower plants with capacity up to 5 MW are customarily classified as SHP. A much higher limit of 30 MW has been preserved in Russia since the Soviet era; however, many publications regarding SHP in Russia assume the threshold of 25 MW.

The EU member states submit annual reports on SHP generation as divided into two installed capacity categories: up to 1 MW and in the range between 1 MW and 10 MW. This approach allows disregarding national legislations which use different capacity limits in the SHP definition.

Regional small hydropower overview

The current situation of the SHP sector remains diverse depending on the available potential, economic conditions and the balance of political power between the parties of national environmental disputes. The fundamental difference between the SHP sectors in the EU member states and other countries under consideration lies in the ownership structure. Large corporations and companies (even if private) heavily prevail in the former Soviet republics, whereas small private enterprises dominate among the EU member states. This has an impact on the investment structure, as large companies are often reluctant to invest in small dispersed installations with profitability heavily dependent on the unstable support systems.

SHP has been the hydropower branch best accepted and even supported among the EU member states that have joined the Union after the year 2000. The main reason is its relatively low environmental impact, especially after implementing restrictive regulations on biological continuity and introducing new, highly specialised technologies. Using the existing dams and weirs for the development of SHP schemes has been considered the best option for a long time.

Based on the available data, the current installed capacity of SHP up to 10 MW in the region is reported to stand at 1,903 MW, which accounts for 44 per cent of the estimated potential (Table 2). However, when taking into account the up to 30 MW definition of SHP in Russia, the region's potential increases to nearly 830 TW, of which only 0.3 per cent has been developed (Figure 2). Following the national reports, Bulgaria, the Czech Republic and Romania have already used a significant portion of their SHP potential, while merely 0.01 per cent of it has been tapped so far in Russia. Significant resources also still exist in Slovakia and Ukraine. Relatively low use of their potential (below 20 per cent) exists in Belarus, Moldova and Poland. Compared to the *WSHPDR 2016*, the region's installed capacity increased by approximately 1.5 per cent (Figure 3).

Table 2.
Small hydropower capacities in Eastern Europe (local and ICSHP definition) (MW)

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed (<10 MW)*	*Potential (<10 MW)*
Belarus	up to 10	18.0	250.0	18.0	250.0
Bulgaria	up to 1	N/A	N/A	486.0	580.7
Czech Republic	up to 10	337.0	465.0	337.0	465.0
Hungary	up to 5	16.5	55.0	16.5*	55.0*
Moldova	up to 10	0.4	3.0	0.4	3.0
Poland	-	-	-	294.8	1,500.0
Romania	up to 10	404.0	730.0	404.0	730.0
Russian Federation	up to 30	826.5	825,845.0	169.6	169.6**
Slovakia	up to 10	81.6	241.4	81.6	241.4
Ukraine	up to 10	95.0	375.0	95.0	375.0
Total		-	-	**1,903**	**4,370**

Source: *WSHPDR 2019*[3]

Note: * Data as per the local definition of SHP. **The estimate is based on the installed capacity as no data on potential capacity is available.

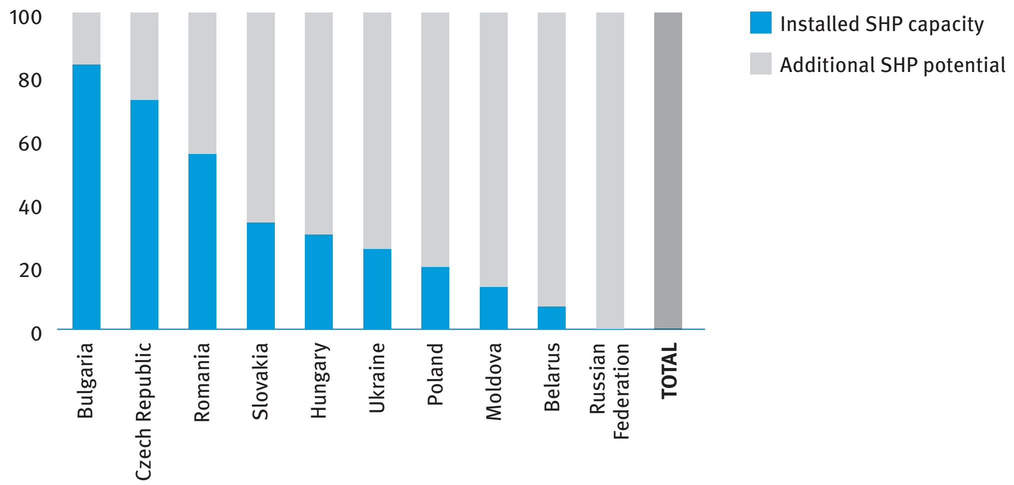
An overview of SHP in the countries of Eastern Europe is outlined below. The information used in this section is extracted from the country profiles, which provide detailed information on SHP capacity and potential, among other energy-related information.

The installed capacity of SHP up to 10 MW in **Belarus** stands at 18 MW, while the potential is estimated at 250 MW. The 2 MW increase in installed capacity, compared to the *WSHPDR 2016*, has been achieved due to the introduction of new capacities in the private sector.

Bulgaria currently has 237 SHP plants up to 10 MW with a combined installed capacity of 486 MW. Multiple attempts have been made to encourage investment in the country's SHP sector, with 84 per cent of the estimated potential developed to date. Since the *WSHPDR 2016*, the installed capacity increased by nearly 200 MW.

In the **Czech Republic**, the installed capacity of SHP up to 10 MW is 337 MW with generation of 1,053 GWh per year. The economically feasible potential of SHP is estimated at 465 MW, indicating that approximately 72 per cent has been developed. The National Renewable Energy Action Plan (NREAP) foresees an increase in the capacity of SHP to 344 MW by 2020.

Figure 2.
Utilized small hydropower potential by country in Eastern Europe (local SHP definition) (%)



Source: *WSHPDR 2019* [3]

Note: This Figure illustrates data for local SHP definitions or the definition up to 10 MW in case of the absence of an official local one. For Bulgaria, the data is presented for the SHP definition up to 10 MW due to the absence of data on installed and potential capacity according to the local definition.

According to the most recent data available, the number of SHP plants up to 5 MW in operation in **Hungary** is 28, with a combined installed capacity of 16.5 MW and an annual generation of 68.7 GWh in 2016. Due to the relatively unfavourable natural conditions, the total hydropower potential in Hungary is rather modest. The technical potential of smaller rivers (up to 5 MW) is estimated at approximately 55 MW with an annual generation of 300 GWh. Compared to the results of *the WSHPDR 2016*, the installed capacity decreased by almost 15 per cent and potential capacity increased by 96 per cent – both due to access to more accurate data.

During the Soviet Union period, there were 17 SHP plants in the **Republic of Moldova**. At present, there is only one functional small-scale hydropower plant, which has a capacity of 254 kW and a maximum annual contribution of 81 MWh. In addition, there are six micro-hydropower plants with a combined capacity of 141 kW, which are, however, not functional. The increase in installed capacity compared to the *WSHPDR 2016* is due to data recently made available. After assessing all potential sites, only 3 MW of potential was discovered for plants up to 10 MW.

Poland has 756 SHP plants with capacity up to 10 MW. Their combined installed capacity is 294.8 MW, representing 29.8 per cent of the country's total hydropower installed capacity and indicating an increase of 2.2 per cent since the *WSHPDR 2016*. In 2016, electricity generation from these SHP plants amounted to 908 GWh. In addition to the developed capacity, 162 SHP projects (up to 10 MW), with a total capacity of 55.97 MW and an expected annual generation of 252 GWh, are reported to be under construction or in the process of obtaining permits. It is estimated that these projects could be finalized by 2030. The total technical hydropower potential for SHP plants (up to 10 MW) in Poland is estimated to be approximately 5 TWh/year, corresponding to at least 1,500 MW of potential installed capacity.

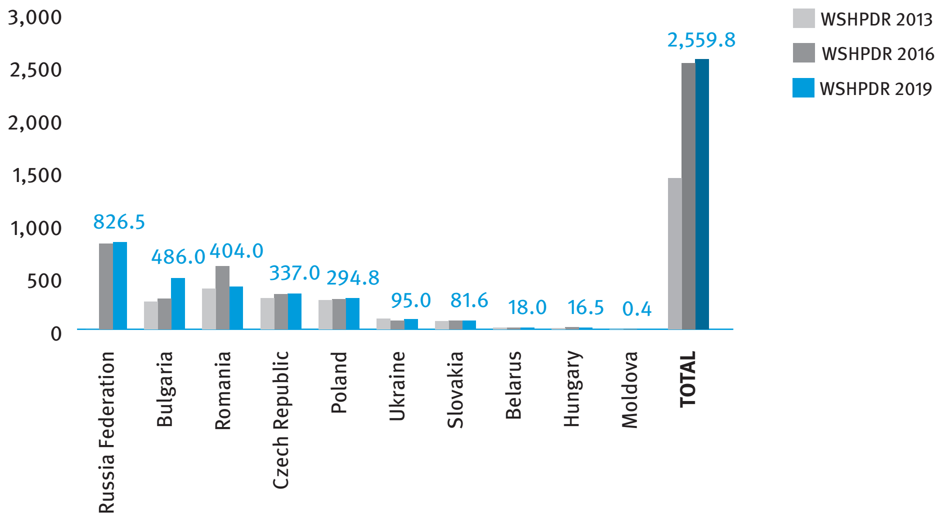
The installed capacity of SHP up to 10 MW in **Romania** is 404 MW, while the potential capacity is estimated to be 730 MW, indicating that approximately 55 per cent has been developed. Since the *WSHPDR 2016*, the installed capacity has decreased by 194 MW due to a more accurate assessment.

In the **Russian Federation**, the installed capacity of SHP plants up to 10 MW is 169.6 MW, and up to 30 MW is 826.5 MW, while the technically feasible potential for SHP up to 30 MW is estimated to be 826 GW, indicating that only about 0.1 per cent has been developed. Since the *WSHPDR 2016*, the number of operating SHP plants up to 30 MW has increased from 134 to 139. However, only two new SHP plants were actually constructed in this period, while other SHP plants were identified from the historic data. There are twelve SHP plants currently under construction across the country with a total installed capacity of about 170 MW. In addition, there are several SHP development plans and opportunities for new SHP projects are being explored.

Slovakia has a total SHP (up to 10 MW) installed capacity of 81.6 MW from 217 plants and with annual generation of 281.8 GWh. The potential is estimated to be at least 241.4 MW, indicating that approximately one-third of the total potential has been developed. Compared to the *WSHPDR 2016*, both the installed capacity and estimated potential capacity have not changed.

The total installed capacity of SHP up to 10 MW in **Ukraine** stands at 95 MW, coming from about 150 plants. The SHP potential capacity is estimated at 375 MW with an annual electricity generation of 1.27 TWh/year. This estimate is based on the 10 MW definition of SHP, as opposed to the 30 MW threshold on which the previous estimates were based. It also takes into account the national laws and programmes as well as international agreements, conventions and additional protocols on protection, conservation and sustainable use of natural resources, which define restrictions on the use of small river resources. The country's electricity is currently influenced by the complex political situation, with the ongoing conflict deepening the economic crisis. Nonetheless, Ukraine still remains a significant local exporter of electricity, and the Ukrainian authorities also declared their commitment to continue developing the national hydropower sector – mainly in order to increase its power system flexibility, security and independence.

Figure 3.
Change in installed capacity of small hydropower from *WSHPDR 2013* to *2019* by country in Eastern Europe (MW)



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

Note: *WSHPDR* stands for *World Small Hydropower Development Report*. For the Russian Federation, data is for SHP up to 30 MW; for other countries up to 10 MW.

After bad experiences with green certificates in several European countries, **feed-in tariff (FITs)** and feed-in-premium systems have been introduced for the smallest installations. For larger ones the auction system is often applied. In most cases the duration of support under auction systems and stipulated tariffs is 15 years. The support period is almost twice as short in the Russian Federation where higher pay-back rates are assumed. Generally, the support package also includes the obligation of public electricity providers to acquire the electricity generated from renewable energy, although this obligation may be subject to limitations. FITs have been introduced by all countries in the region, except Romania, while the Russian Federation offers some compensation for investment costs to renewable energy projects selected on a competitive basis. Some other measures of support, such as exemption of taxes and access to support funds are also available locally.

Except Romania, Hungary and Slovakia, the SHP sector in the region has seen positive or no change since the previous *WSHPDR*. However, the general conditions for SHP development are significantly worse than at the beginning of the decade. The general trend is to support the investment by shortening the pay-back period, while long-term support is lacking. At the same time, the feeling of uncertainty, instability and balancing at the edge of economic profitability prevailed in the EU member states in the region throughout the recent period. As profitability of the existing plants became endangered, refurbishments have been often considered as a tool to regain the public support. On the other hand, some positive signs have been noticed – both internally and from the international community, there is ever more commitment to mitigate the climate change effects and develop renewable energy.

Barriers to small hydropower development

The common background for all administrative and most of economic problems encountered is a poor image of hydropower in the eyes of local societies. The sector is often perceived solely as a source of moderate amounts of green energy and easy income to the owner at the cost of significant interference with the environment. The multipurpose character of SHP installations and numerous benefits for water management and the environment as well as local power grids are usually disregarded. The capacities of national hydropower associations are usually not sufficient for this purpose. Some hopes may be linked with ever better understanding of the climate change consequences and the need for their mitigation and relevant counteraction wherever possible as a top priority for the humankind.

While economic constraints may be considered as one of the main factors hampering faster growth of the sector in Russia, Ukraine and Moldova, the environmental policy of the EU and local green movements stand often behind the slow-down of hydropower growth among its Eastern European members after joining the EU. Green movements often take part in local political campaigns as independent subjects or can be used by the main actors of the political arena. The consequence is a diversity of approaches to the hydropower sector among the EU countries.

In addition to the financial issues, in **Belarus**, SHP development is limited by the fairly flat terrain in the northern and central parts of the country where most of the potential is concentrated, as well as by the low cost of natural gas and limited policy framework.

In **Bulgaria**, obtaining authorization for the construction and operation of SHP plants is a lengthy process that frequently deters investors from completing SHP projects. In addition, with approximately 60 per cent of the rivers being located in protected areas, environmental impact assessments are required to be very thorough and are therefore expensive. There is also a need for updated information on the SHP potential.

SHP development in the **Czech Republic** is hindered by the high cost of operation and maintenance of plants, the fairly complex licensing procedure as well as the priority of fossil fuels and nuclear power in the country's energy strategy over renewable energy sources.

No major barriers to SHP development have been identified for **Hungary**. However, as the most suitable sites have already been developed, no significant development in the SHP sector is currently expected.

Besides the lack of funding, growth of the SHP sector of the **Republic of Moldova** is hindered by the high costs of SHP development due to the lack of local market technologies and the high costs of imported equipment, the need for individual design of each installation due to the lack of standardized concepts, as well as the costly and time-consuming process of connection to the electricity network.

The key barriers to SHP development in **Poland** are legal uncertainty, the inadequacy of the current support schemes, the financial difficulties of maintaining existing plants, constraints preventing financing hydropower investments from the EU Funds, the lack of effective and common regulations allowing the utilization of existing weirs for hydropower purposes, and the lack of spatial development plans in which SHP projects would be included.

The key issues hampering the development of SHP in **Romania** are the lack of legislation for the promotion of renewable energy, a very complex procedure of obtaining the Water Management Approval and securing a location for plant development, the high cost of water use for power generation and protests against the development of SHP in the upper sector of the mountain areas.

The main barrier to the developing of SHP, the same as of other renewable energy sources, in the **Russian Federation** is the availability of vast fossil fuel resources and their importance to the economy. SHP development does not receive state support and excessive requirements are imposed by the regional grid companies for the provision of grid connection. The procedures of land allocation and state approvals for the projects are lengthy. There is a shortage of up-to-date scientifically proven data on the regional capacity for developing SHP projects, a lack of standard technical and methodological regulations, information technologies and software required for designing, constructing and operating renewable energy plants as well as a lack of training for specialists and skilled professionals at the regional level.

In **Slovakia**, there is little activity amongst investors in the SHP sector due to the fears of a long return of investment, and the complex process of obtaining permits. Government bodies have no active role in the development of SHP plants, because the country has a stable power generation base with no need for further development of power plants. Furthermore, there is a mistrust towards the construction of SHP plants from the general public and environmental activists.

Among the main barriers to SHP development in **Ukraine** are high bank interest rates, the lack of normative and technical basis of parallel operation of SHP plants and regional grids, high prices for electricity transmission and environmental issues. In addition, some Government acts can prolong construction and increase costs.

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4.1.1

Belarus

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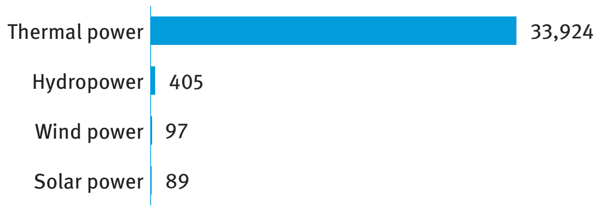
Key facts

Population	9,491,900[1]
Area	207,599 km[2]
Climate	The country is in the transitional zone between continental and maritime climates. In the winter, the climate is cold with average temperatures, in January, ranging from –4 °C in the south-west (Brest) to –8 °C in the north-east (Vitebsk). In the summer, the climate is cool and moist, with average high temperatures in July of 18 °C.[2,14]
Topography	The Republic of Belarus is a landlocked country. It is relatively flat and contains large tracts of marshy land. It has mountain ridges located in the west and north-west of the country with the highest peak Mount Dzyarzhynskaya at 345 metres. About 40 per cent of Belarus is covered by forest.[2]
Rain pattern	Belarus has an average annual rainfall of 500 to 800 mm. Precipitation is highest in July, with an average rainfall of 85 mm, and lowest in February, with an average of 33 mm.[14] The rainfall is heaviest in the central and north-western parts of the country.[2]
Hydrology	There are around 20,800 rivers with a total length of 90,600 km along with 10,800 lakes, 153 water reservoirs and 1,500 ponds. Some of the longest rivers in the country include the Dnieper, Sozh, Western Dvina, Western Boug, Neman, and Vilia. The Black Sea is the river basin for the rivers of Dnieper, Sozh and Pripyat and collects on average around 55 per cent of the river runoff. The Baltic Sea is the river basin to the Western Dvina, Neman, Vilia, Western Boug and collects on average 45 per cent of the accumulated river runoff. [2]

Electricity sector overview

In 2017 power generation in the Republic of Belarus amounted to 34,515 GWh, with 98 per cent of the total production coming from the thermal power stations (33,924 GWh), 405 GWh was produced by the hydropower stations, 97 GWh by the wind turbines and 89 GWh by the solar photovoltaic systems (PV); the losses from distribution amounted to 2,872 GWh. Figure 1 shows the electricity generation of the Republic of Belarus in 2017. Electricity imports in 2017 amounted to 2,733 GWh and exports to 148 GWh, therefore, electricity consumption was 37,100 GWh.[3] The electrification rate in the Republic of Belarus is 100 per cent.[8]

Figure 1.
Annual electricity generation by source in Belarus (GWh)



Source: National Statistical Committee of the Republic of Belarus[3]

Electricity generation in Belarus is predominantly supplied through the use of thermal power based on various fuel sources, with the vast majority coming from natural gas (more than 90 per cent), oil, associated gas, coal and peat. As of January 2019, the total installed capacity of all the power generating energy sources of the Republic of Belarus was 10,069 MW. The Belarusian energy system included 68 energy generating plants. The installed capacity of 64 energy generating plants, under the ownership of Belenergo, was 8,938 MW, of which 42 were thermal power plants (TPPs) with a total installed capacity of 8,841 MW, 12 were high-pressure thermal power plants (8,188 MW), 25 were hydroelectric power plants (HPPs) with a total installed capacity of 88 MW and one was a wind power plant (WPP) with an installed capacity of 9 MW.[5] The State Production Association (SPA) Belenergo is a subordinate of the Ministry of Energy of Belarus and one of their main objectives is the generation, transmission, distribution and sale of electricity and thermal energy.[6]

In 2017 two newly built HPPs were put into operation – Polotsk HPP with an installed capacity of 21.75 MW and Vitebsk HPP with an installed capacity of 40 MW. In addition, by 2020, the SPA Belenergo plans to develop a new hydropower plant on the Western Dvina – Beshenkovichi HPP with a planned installed capacity of 29 MW, the construction of which requires investment.[7]

The electricity tariffs in Belarus can be split into two general categories – single-rate and differentiated. The differentiated tariff rate depends on the time period of electricity consumption (minimum or maximum load). Table 1 shows how the tariffs are allocated in U.S. dollars per kWh. As can be seen, the prices for households are significantly lower than for other types of users.

Table 1.
Electricity tariffs (US$/kWh)

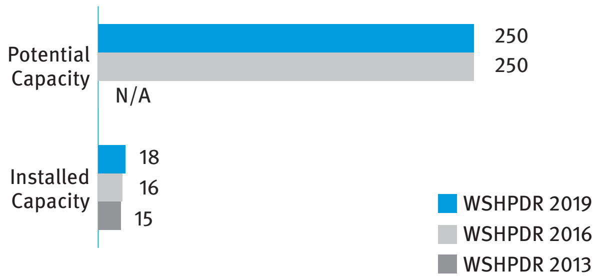
Type of user	*Tariff (US$/kWh)*
Households	0.04-0.14
Industrial and governmental organizations, incl.:	0.07-0.15
Street lighting and railway transport	0.13
Agricultural consumers	0.09
Transport	0.10-0.13

Source: Belenergo[4]

Small hydropower sector overview

The definition of small hydropower (SHP) in the Republic of Belarus is 10 MW or less. The installed capacity of small hydropower, as of 2016, was estimated at 18 MW.[9] SPA Belenegro operates 22 of these SHP plants that have a combined installed capacity of 9.4 MW.[5] The installed capacity of state-owned SHP plants has not increased since the previous *World Small Hydropower Development Report* publication, meaning that the privately owned SHP installations have increased in capacity by 2 MW. Figure 2 shows the comparison of the potential and installed capacities between *WSHPDR 2013, WSHPDR 2016* and *WSHPDR 2019.*

Figure 2.
Small hydropower capacities 2013/2016/2019 in the Republic of Belarus (MW)



Source: IRENA,[9] *WSHPDR 2013,*[10] *WSHPDR 2016*[11]

Note: The comparison is between the data from *WSHPDR 2013, WSHPDR 2016* and *WSHPDR 2019.*

Since the publication of the *World Small Hydropower Development Report 2016,* new SHP feasibility studies have not been carried out. The last SHP evaluation which took place in 2010 concluded that the gross theoretical SHP potential is 850 MW, with a technically and economically feasible potential evaluated at 520 MW and 250 MW, respectively.[11]

Only about 7 per cent of the small hydropower potential has been utilized in Belarus, however the installed capacity has increased by about 13 per cent since the previous *World Small Hydropower Development Report* publication in 2016.

Renewable energy policy

The main policy which determines the development of renewable energy is the legal act of the Government of the Republic of Belarus of December 27, 2010 № 204-Z called the "Renewable Energy Sources". The main objective of the policy is to diversify the sources of electricity generation between 2011 and 2020.[12,13] In 2015 two legal acts entered into force in the Republic of Belarus. These were put in place to regulate the procedure of the establishment and allocation of quotas when creating installations using renewable energy sources:

- Decree of the President of the Republic of Belarus on the "Use of Renewable Energy Sources" of May 18, 2015 No. 209.
- Resolution of the Government of the Republic of Belarus of August 6, 2015 No. 662 on "Establishing and distributing of quotas for creation of renewable energy plants".[13]

In 2017, the Ministry of Antimonopoly Regulation and Trade of the Republic of Belarus issued Resolution No. 41, which defines the tariff system for electricity produced from renewable energy sources by individual entrepreneurs and legal entities that are not members of the SPA Belenergo.[13]

Barriers to small hydropower development

The main barriers to small hydropower development in Belarus are outlined below.

- Most of the small hydropower potential is in the northern and central parts of the country where the landscape is mainly made of plains and is fairly flat, and only low head power installations are operational.
- More comprehensive policies that are able to facilitate investments in small scale renewable energy would be needed to encourage the small hydropower development.
- The financial issue is the most critical barrier to small-scale power generation in Belarus. Between having to compete with low cost fuels, namely natural gas, and the need to attract private investors, development in small hydropower is problematic.[10]

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4.1.2 Bulgaria

International Center on Small Hydro Power (ICSHP)

Key facts

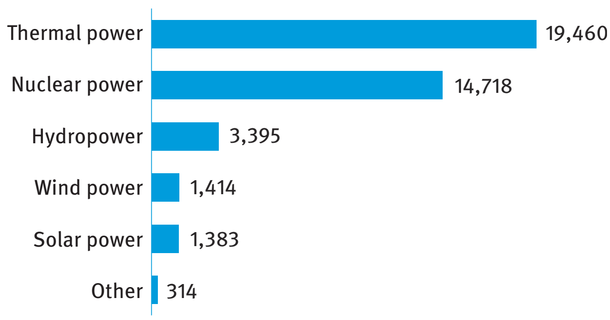
Population	7,127,822 [1]
Area	111,002 km[2]
Climate	The climate of Bulgaria is temperate, characterised by cold, damp winters and hot, dry summers. Along the coast of the Black Sea, the climate is slightly milder. Cold air masses from northern Europe and the Russian Federation influence the weather of the country, as well as the warm air masses from the Mediterranean and North African region. The average temperature in the north is -1 °C in January and 22 °C in July, while the south is a bit warmer, reaching on average 1 °C in January and 23 °C in July. The average minimum temperature for the Danube Plain is the lowest in the entire country at -25 °C. Summer temperatures exceeding 30 °C are common in the south-west of the country, and hot days with temperatures peaking at 40 °C are also not unheard of.[2,3]
Topography	Musala peak is part of the Rila Mountains in Bulgaria and is the highest in the entire Balkan Peninsula, standing at 2,925 metres. Most of the country is characterised by low plateaus and hilly land, with an average altitude of 470 metres. The four alternating bands of high and low terrain represent an intrinsic part of Bulgaria's topography. These bands are the Danubian Plateau in the very north, followed by the Balkan Mountains, the central Thracian Plain and the Rhodope Mountains.[2,4]
Rain pattern	Annual average precipitation is estimated at 579 mm. May and June are the wettest months of the year, rainfall reaching over 68 mm, while February, August and September are the driest, with a monthly average under 42 mm. The data was collected as a part of the World Bank project and measures monthly rainfall between 1901 and 2015.[5]
Hydrology	The Danube is the only navigable river in Bulgaria. However, the country has a network of roughly 1,200 rivers of various sizes. Apart from the Iskur river (368 km), which rises in the Rila Mountains and flows northward to the Danube, all rise in the Balkan Mountains and flow into the Aegean Sea or into the Black Sea. Bulgarian rivers and streams have a high potential for production of hydroelectric power and are sources for irrigation water.[4]

Electricity sector overview

Gross electricity generation in 2017 was 40,684 GWh (Figure 1). Electricity produced through coal and gas accounted for 19,460 GWh, nuclear power 14,718 GWh and hydropower 3,395 GWh. While thermal power plants (TPP) are still the largest contributor, an increase in electricity generation from both nuclear and renewable energy resources was observed. Solar power accounts for 1,383 GWh, wind power 1,414 GWh and 314 GWh are produced from other resources.[7] In 2017, the total installed capacity was 12,070 MW. These statistics included 5,044 MW from the thermal plants, 3,204 MW from the hydropower plants (HPP), 2,000 MW the nuclear power plants (NPP) and 1,822 MW other renewable resources.[7]

Figure 2 shows the installed capacity by source. The decrease in total installed capacity between the previous report and the current one may be explained by the nature of the statistics used. While the previous report offers total, estimated installed capacity, the current report refers to available capacity, assessed after a more thorough research conducted in the country.

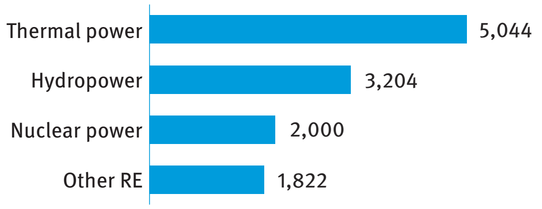
Figure 1.
Annual electricity generation by source in Bulgaria (GWh)



Source: EWRC[7]

The country's electrification rate reached 100 per cent, according to the more recent statistics made available in 2016.[8] The reliability of power supply improved due to the changes made in the energy management system. The Supervisory Control and Data Acquisition (SCADA) division is in charge of monitoring outages and service restorations.[9] The Energy and Water Regulatory Commission (EWRC) establishes the national electricity tariffs in Bulgaria. According to the decision approved on the July 1st, 2018, new prices for the supply of electric power to households were adopted. The prices provided in Table 1 below include the access and the transmission tariffs for customers, the value-added tax (VAT) being excluded.[10]

Figure 2.
Installed electricity capacity by source in Bulgaria (MW)



Source: EWRC[7]

Table 1.
Electricity tariffs for household consumers in 2018 in Bulgaria

Method of measuring	*Time zones*	*Price (US$/kWh)*	*Total price (US$/kWh) including grid services*
With two scales	Day	0.083	0.110
	Night	0.033	0.063
With one scale		0.083	0.110

Source: Energo-Pro Bg[10]

Table 2.
Electricity tariffs for non-household consumers in 2018 in Bulgaria

Con-sumption band	*Annual electricity consumption (MWh)*		*Tariff (US$/kWh)*		
	Lowest	*Highest*	*Excluding taxes and levies*	*Excluding VAT and other recoverable taxes*	*Including all taxes, levies and VAT*
			(Level 1)	*(Level 2)*	*(Level 3)*
Band - I1		<20	0.130	0.130	0.150
Band - I2	20	< 500	0.100	0.100	0.120
Band - I3	500	<2,000	0.086	0.087	0.100
Band - I4	2,000	<20,000	0.077	0.078	0.094
Band - I5	20,000	<70,000	0.072	0.073	0.088
Band - I6	70,000	≤150,000	0.067	0.068	0.081
Band - I7		> 150,000	0.063	0.064	0.077

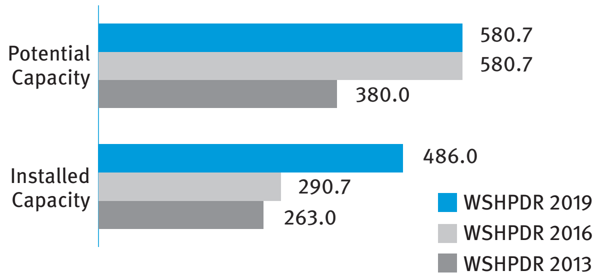
Source: NSI[11]

The price for access to the electricity grid is 0.005 US$/kWh and the tariff for transmission is 0.020 US$/kWh. Electricity costs for industry are expected to increase. According to EWRC, the increase in the "duty to society" tax will cause a change in the electricity tariffs for industry. Current non-household customer electricity tariffs were made public on March 2018 by the National Statistics Institute in the Republic of Bulgaria. Table 2 offers more information on electricity tariffs for non-household consumers in 2018.[11]

Small hydropower sector overview

The definition for small hydropower (SHP) in Bulgaria refers to plants with capacities between 50 kW and 1 MW, while plants from 1 MW to 10 MW are considered of medium size, and plants below 50 kW are classed as micro-hydropower. For data comparison-related reasons, the report considers small hydropower as plants equal to or below 10 MW. The information offered in this section is also for plants up to 10 MW. There are currently 237 small hydropower plants in the country. SHP installed capacity is 486 MW, representing an increase from the *World Small Hydropower Development Report 2016*. Small hydropower potential was estimated at 580.7 MW based on the feasibility studies conducted in the country. No further updates were made so far on SHP potential capacity data.[16,19]

Figure 3.
Small hydropower capacities 2013/2016/2019 in Bulgaria (MW)



Source: *WSHPDR 2013*,[15] *WSHPDR 2016*,[16] ESHA,[17] Hydroenergy Association[19]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

Multiple attempts have been made in Bulgaria to encourage investment in the small hydropower sector. Successful projects such as the SHP plant which resulted as a collaboration of Delectra Hydro JSC with Beerecl were made available to the wider public. Therefore, information on the invested amount as well as generated annual revenue is frequently made available to parties actively interested in the development of the small hydropower sector. The transparency of the information positively affects the dynamics of the SHP sector in Bulgaria.

Renewable energy policy

Multiple initiatives were adopted in 2017 to ensure the efficient promotion of sustainable development and dissemination of renewable energy policy in Bulgaria. The following programmes were submitted to the European

Commission on May 2017: (a) The updated version of the National Energy Efficiency Action Plan 2014-2020, (b) The National Plan for the Improvement of Energy Performance of heated and cooled state-owned buildings used by the state administration in 2016-2020, and (c) The National long-term Programme for the Promotion of Investments in measures aimed at improving the energy performance of the national stock of public and private residential and commercial buildings 2016-2020.[12]

On the 20 December 2017 Resolution No. 796 was officially adopted, and the document defining the energy saving targets for each individual electricity trader in Bulgaria was made available. The combined targets of electricity saving were agreed at an impressive total of 215 GWh. Heat traders agreed to attempt saving 49 GWh of energy, while the natural gas, liquid fuel and solid fuel traders total energy-saved targets reached 73 GWh, 7 GWh and 36 GWh respectively.[13]

In Bulgaria renewable energy generation is supported through a feed-in tariff scheme. The feed-in tariff (FIT) applies to producers of electricity from renewable sources. The amount of tariff is determined by the Energy and Water Regulatory Commission (ERSA). The payment specified by the ERSA is a guaranteed payment. The feed-in tariff cannot be changed during the entire term of the subsidy agreement. The feed-in tariff is based on the date the plant was put into operation. Only the quantities up to the amount of "net specific production "(NSP), as defined by the EWRC, are bought at the preferential price. The NSP is defined as the average annual electricity output for installations from 1 kW of installed capacity after deducting the own electricity consumption of the RES producer.[20]

The public provider is obliged to buy electricity produced from renewable sources at a preferential price for the quantities of electricity up to the NSP. The period of the obligation to purchase and dispatch electricity depends on the subsidy agreement between the plant operator and the grid operator. The term of such an agreement is 20 years for the plants using geothermal energy, biomass and solar energy, 15 years for plants using biogas and hydropower (the hydropower plants with installed capacity exceeding 10 MW are not covered by the promotion scheme), and 12 years for the wind power plants. In 2015, the Bulgarian parliament has amended The Energy Act and removed feed-in tariffs for new renewable projects. The value of the FIT varies depending on the type of the HPP – derivative or the run-off river. The tariff range is between 112.10 BGN/MWh (66.26 US$/MWh) and 222.83 BGN/MWh (131.71 US$/MWh).[20]

With the aim of supporting increased generation and meeting its renewable energy targets, the Government of Bulgaria implemented a series of sector policies, including the aforementioned FITs, to support the development of renewable energy sources and high-efficient co-generation plants, in particular solar PV, wind, biomass, biogas, and small hydropower plants. Increasing financial costs arising from the factors both contractual (long-term power purchase agreements) and legal (feed-in tariffs and co-generation bonuses), coupled with a reduced demand in the regulated sector, have put significant pressure on the electricity tariffs. As a result of the revenue and cost mismatch in the regulated sector, large tariff deficits emerged in recent years, tariff deficit being defined as the "shortfalls of revenues in the electricity system arising when retail electricity tariffs are set below the corresponding costs borne by the energy companies".[19] With the objective of keeping prices low, a series of government policies were implemented – most notably, ad-hoc amendments to the legal and regulatory framework were designed to limit the costs of renewable energy generation."[19]

The set of measures implemented include:

- Allocating the revenues from the sale of quotas for greenhouse gases to offset the costs set by the National Electricity Company (NEK) in order to meet its contractual and legal obligations under the Energy Law – such as long-term PPAs, renewable energy, and high efficient cogeneration (these revenues, estimated at BGN 130 million (US$ 75.3 million) in 2015, are collected in the Energy Security Fund (ESF), which is under the Ministry of Energy);
- Setting up a fee for all power generators equivalent to 5 per cent of monthly income from electricity sold (these revenues are also collected in the ESF);
- Restricting the quantities of electricity purchased by NEK from renewable energy producers at feed-in tariffs. These volumes are based on the reference values in the regulatory resolutions in which the feed-in tariffs were set. Electricity produced above such limits is to be sold on the free market.[19]

A new financial model was developed in order to assess the financial gap and to identify short- and medium-term options to financially stabilize the power sector. The financial stabilization of the sector requires a combination of several measures, including the integration of independent power producers and renewable energy producers into a competitive wholesale market.

Feed-in premium tariffs are the preferred transition mechanisms for IPPs. More recently, other EU countries have also used this mechanism to help the producers of renewable energy to integrate into a competitive market. It is recommended that Feed-in premiums are used to facilitate the integration of other market players into the competitive market (e.g. smaller size RE producers benefiting from FITs and co-generation facilities benefiting from cogeneration bonuses) could be implemented in a later stage. The new model enters into force on 1 January 2019. The essence of this mechanism is that the producers will not receive preferential prices for the produced energy, instead they will receive a fixed premium for each produced MWh. The premium represents the difference between the preferential price received so far and the estimated market price determined annually by the Regulator (Energy and Water Regulatory Commission).[19]

As a result of the renewable energy policy, in 2012, both the production and consumption of energy from the renewable energy sources (RES) rose substantially. Bulgaria achieved its target of 16 per cent RES share in gross final energy consumption.

Barriers to small hydropower development

The country made efforts to ensure efficient dissemination of small hydropower projects, however there are still several obstacles to SHP development:

- Obtaining authorization for the construction and operation of small hydropower plants is a lengthy process that frequently deters investors from completing SHP projects.[16]
- Environmental impact assessments have to be very thorough and therefore expensive, because approximately 60 per cent of the rivers in Bulgaria are located in protected areas of the country.[16]
- Not enough information on the small hydropower potential in Bulgaria is made available, there are no recent studies on the hydropower potential.

To ensure better integration between different policies, an increase in the transparency of decision-making is necessary. Significant progress in policy integration can be made by enhancing the recognition of different interests, fostering co-operation between the various authorities and stakeholders, and promoting more integrated development strategies. The integration of water and energy policies is beneficial since it will create synergies and avoid potential inconsistencies as well as mitigating possible conflicts between water users.

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4.1.3

Czech Republic

International Center on Small Hydro Power (ICSHP)

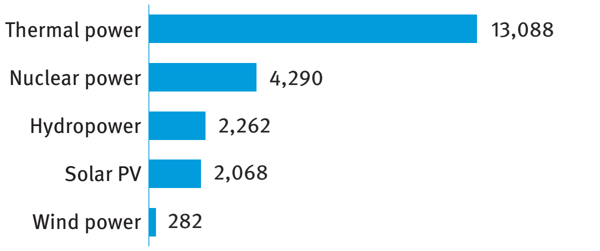
Key facts

Population	10,566,332[1]
Area	78,864 km[2]
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 lower areas of the country but decrease at higher elevations. January is the coldest month with average temperatures in the lowlands going 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 lowlands.[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. Mount Sněžka at 1,603 metres is the highest point of the country and lies in the east in the Krkonoše Mountains.[3]
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 and 800 mm.[2]
Hydrology	The major rivers are the Elbe, which drains most of the territory of Bohemia and flows into the North Sea, the Morava River, which drains a major part of Moravia and flows into the Danube River, and the Odra River flowing into the Baltic Sea. The highest discharge is observed in spring months as a result of snow melting.[2,3]

Electricity sector overview

The total installed capacity of the Czech Republic in 2016 reached 21,989 MW (Figure 1). The electricity sector of the country is dominated by the thermal power, which accounted for almost 60 per cent of the total installed capacity, while hydropower contributed only 10 per cent. The installed capacity of hydropower plants, including pumped storage, was 2,262 MW, of which pumped storage hydropower accounted for more than half (1,172 MW).[4]

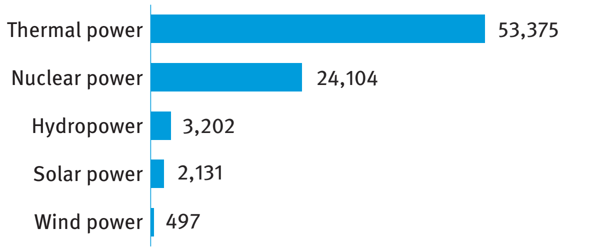
Figure 1.
Installed electricity capacity by source in the Czech Republic (MW)



Source: ERO[4]

In 2016, a total of 83.3 TWh was generated by the electricity sector of Czechia. Thermal power (including combined cycle plants) and nuclear power together contributed almost 93 per cent, whereas renewable energy sources contributed the remaining 7 per cent (Figure 2).[4] Electricity generation from renewable sources grew in the years 2014-2016. At the same time, the output of nuclear power plants has been decreasing in the last few years, although their installed capacity has remained unchanged.[4]

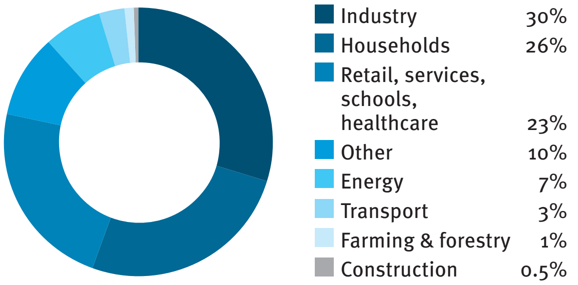
Figure 2.
Annual electricity generation by source in the Czech Republic (GWh)



Source: ERO[4]

Electricity consumption in 2016 increased by 2 per cent compared to 2015 and reached 72.4 TWh, with the most pronounced increase having been observed in the household sector.[4] The industry and residential sectors accounted for 56 per cent of total consumption (Figure 3). The annual peak load in 2016 was registered in December at 11,410 MW and the minimum load in August at 4,932 MW. Total losses in the electricity network amounted to less that 2 per cent.[4] The electrification rate in Czechia is 100 per cent.[1]

Figure 3.
Electricity consumption by sector in the Czech Republic (%)



Source: ERO[4]

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. The electricity sector is regulated by the Electricity Industry Department of ERO.[6]

The main participants of the Czech electricity market include a transmission system operator (TSO), distribution sector operators (DSOs), electricity generators, the market operator, electricity traders and consumers. ČEPS is the sole TSO of Czechia, which holds an exclusive licence to maintain and operate the transmission system. ČEPS is a state-owned enterprise and is controlled by the Ministry of Industry and Trade. The transmission system comprises 41 substations and 71 transformers, 3,508 km of 400 kV lines and 1,910 km of 220 kV lines.[5] Conversely, the distribution network is privately operated. The major DSOs are ČEZ Distribuce serving over 3.6 million end users and E.ON Distribuce serving 2.8 million users.[7,8] The distribution network is comprised of lines at voltage levels ranging from 0.4 kV to 110 kV. The Czech electricity market is operated by OTE, which organizes trading in the day-ahead, intra-day and block electricity markets, provides data processing and exchange services to market players as well as administers the National Register of Greenhouse Gas Emissions.[9]

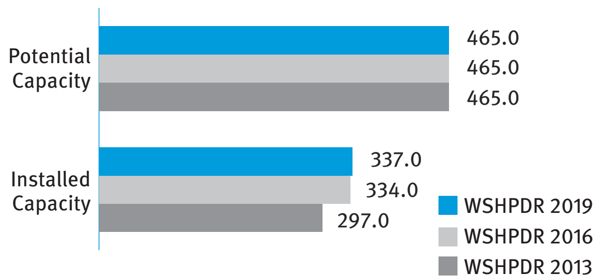
The electricity system of Czechia is connected to the networks of Poland, Germany, Austria and Slovakia through both transition and distribution lines. In 2016, the exchange balance between Czechia and these countries was negative at almost 11 TWh, with approximately 25 TWh of electricity exported and approximately 14 TWh imported.[4]

The price of electricity transmission is regulated by ERO through regular Price Decisions, whereas the price of electricity itself is not regulated and is set by electricity suppliers individually. Besides, the final price includes the fee for the promotion of renewable energy, combined generation of electricity and heat and secondary sources.[10] Final electricity tariffs depend on the consumer category and consumption level. The average electricity price in 2017 was 0.1488 EUR/kWh (0.17 US$/kWh) for household consumers and 0.0710 EUR/kWh (0.0.83 US$/kWh) for non-household consumers.[11]

Small hydropower sector overview

In the Czech Republic small hydropower (SHP) is defined as hydropower with installed capacity up to 10 MW. The installed capacity of SHP in Czechia in 2016 was 337 MW, with a generation of 1,053 GWh.[4] Thus, in 2016, SHP plants accounted for almost 15 per cent of the total installed capacity of all hydropower plants and produced 33 per cent of electricity from hydropower plants (Table 1). The economically feasible potential of small hydropower is estimated at 465 MW, indicating that approximately 72 per cent has been developed.[12] Compared to the *World Small Hydropower Development Report* (*WSHPDR*) *2016*, installed capacity has increased by less than 1 per cent, while estimated potential has not changed (Figure 4).

Figure 4.
Small hydropower capacities 2013/2016/2019 in the Czech Republic (MW)



Source: ERO,[4] *WSHPDR 2016*,[10] Punys & Pelikan,[12] *WSHPDR 2013*[13]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

Hydropower remains the main source of renewable energy in Czechia. However, its share in the energy mix is rather small. This is mainly due to the natural characteristics of rivers and streams, which tend to have low slopes or insufficient flow rates.[10] The large hydropower plants are located on the Vltava River, forming the Vltava River Cascade, whereas SHP plants are mainly located on smaller rivers such as the Morava, Sázava, Ohře, Svratka, Dyje and Berounka. Approximately 86 MW of SHP capacity is located on the Elbe River.[10]

According to the national strategy of renewable energy development, the National Renewable Energy Action Plan (NREAP), in 2020 13.5 per cent of energy should come from the renewable sources. For small hydropower, the Plan foresees an increase of 67 MW – from 277 MW in 2005 to 344 MW in 2020.14 Thus, the remaining SHP capacity to be added to the country's energy mix by 2020 amounts to 7 MW (Table 2).

Table 1.
Hydropower installed capacity and electricity generation in 2016

Hydropower stations	*Installed capacity (MW)*	*Electricity generation (GWh)*
<1 MW	155.9	482.7
1 MW-10 MW	181.5	570.5
>10 MW	752.8	947.4
Pumped storage	1,171.5	1,201.5
Total	**2,261.7**	**3,202.1**

Source: ERO[4]

Table 2.
The National Action Plan for hydropower development by 2020

Year	*2018 (MW)*	*2019 (MW)*	*2020 (MW)*
< 1 MW	152	153	153
1-10 MW	191	191	191
>10 MW	753	753	753
Total	**1,096**	**1,097**	**1,097**

Source: MPO[14]

Renewable energy policy

The long-term goals for the Czech energy sector are outlined in the State Energy Policy. In 2015 the Government approved an update of the Policy for the following 25 years. The Policy defines the long-term vision for the sector as "the provision of reliable, reasonably priced supplies of energy to households and the economy that are sustainable in the long term".[15] For this purpose the Policy identifies 5 strategic priorities:

- Balanced energy mix;
- Savings and efficiency;
- Infrastructure and international cooperation;
- Research, development and innovation;
- Energy security.[15]

In particular, the first priority foresees a transition from the energy mix, currently heavily dependent on coal, towards a more diversified mix. However, a particular focus in this regard is being made on the enhancement of the nuclear sector. The Policy also stresses the need to develop a competitive renewable energy sector with state support and ensure an 18 per cent share of renewable energy sources in the total generation of electricity. At the same time, it emphasizes the limited potential of renewable energy sources in the country.[15]

The 2020 objectives for the renewable energy sector as reflected in the National Renewable Energy Action Plan (NREAP) are to achieve 4 MW of geothermal power capacity, 2,118 MW of solar power, 573 MW of wind power and 364 MW of biomass. The total installed capacity of renewable energy sources is planned to reach 4,156 MW.[14]

In Czechia, renewable energy projects are supported through either a guaranteed feed-in tariff or a green bonus paid on top of the market price. However, in 2013, Act No. 310/2013 de facto abolished the feed-in tariff scheme. As a result, solar power and biogas plants are currently being supported only if they were commissioned before the end of 2013, while wind, hydropower, geothermal and biomass plants are being supported if they were put into operation before the end of 2015 and their building permit was issued before October 2, 2013. However, plants up to 100 kW (30 kW for solar power and 10 MW for hydropower) are excluded from this regulation and can still receive support through the feed-in tariff scheme. Plant operators are free to choose between the feed-in tariff and the green bonus.[16]

The feed-in tariffs are established by ERO on an annual basis. If the producer opts for the feed-in tariff, electricity distributor will be obliged to take all the produced electricity. According to the Act on Promotion of Electricity Production from Renewable Energy Sources, this scheme allows the investment payback within 15 years. Green bonuses are calculated based on the time period passed 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 distribution system operator. Besides these two schemes, renewable energy projects can also receive investment subsidies.[10]

The feed-in tariffs for SHP plants at existing locations and reconstructed SHP plants put in operation in 2018 were set at 2,214 CZK/MWh (100.14 US$/MWh) and for SHP plants at new locations at 2,741 CZK/MWh (123.98 US$/MWh).[17]

Barriers to small hydropower development

The main barriers to SHP development in the Czech Republic include:

- High operation and maintenance costs;
- The priority of fossil fuels and nuclear power in the country's energy strategy over renewable energy sources, which are considered merely complementary;
- SHP development remains a topic of political debate and is, thus, susceptible to the political situation in the country;
- The licensing procedure is fairly complex and often somewhat protracted.[10]

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4.1.4 Hungary

Katalin Varga, Hungarian Energy and Public Utility Regula5ry Authority

Key facts

Population	9,797,561[1]
Area	93,030 km[2]
Climate	Hungary has a temperate climate, with cold, cloudy and humid winters and warm summers. The average annual temperature is between 10 °C and 11 °C. The warmest months are July and August with an average temperature of 21 °C. The coldest months are December and January with an average temperature of 0 °C.[2]
Topography	Hungary is a mostly flat country, 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 in the country is Mount Kekes (1,014 metres) in the Matra Mountains, north-east of Budapest. The lowest point lies at 77.6 metres above sea level, in the Hortobagy.[3]
Rain pattern	Total mean annual precipitation is approximately 600 mm. July is the wettest month, with an average precipitation of 71 mm, and February is the driest, with 29 mm of rainfall.[2]
Hydrology	Hungary has large water resources. The two most important rivers, the Danube (417 km) and the Tisza (596 km), are navigable along the entire length of their Hungarian portions. Lake Balaton (594 km^2) is the largest lake in Central Europe and Lake Héviz (47.5 km^2) is the largest thermal lake in the world.[2]

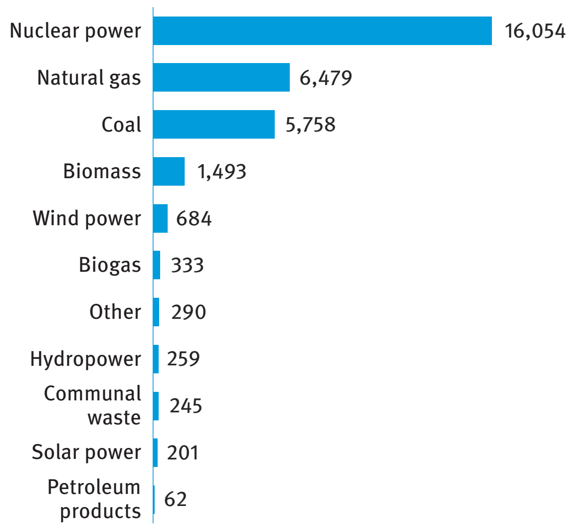
Electricity sector overview

In Hungary, electricity is generated from various energy sources – nuclear, coal (lignite), natural gas, petroleum products, waste, renewable sources (solid biomass, biogas, wind, solar, hydropower, biodegradable waste). In 2016, gross electricity generation in Hungary amounted to 31,859 GWh, with nuclear power accounting for 50.4 per cent, natural gas 20.3 per cent, coal 18.1 per cent, biomass 4.7 per cent, wind power 2.2 per cent, biogas 1.0 per cent, communal waste 0.8 per cent, hydropower 0.8 per cent, solar power 0.6 per cent, oil 0.2 per cent and other sources (blast furnace, coke oven gas, tail gas, non-renewables waste and waste heat) 0.9 per cent (Figure 1).[4]

Thus, in 2016 nuclear energy from the sole state-owned nuclear power plant at Paks (Paksi Atomerőmű) accounted for approximately 50 per cent of the domestic electricity generation in Hungary. The Paks power plant has four reactors with a total gross capacity of 2,000 MW.[4] A permission procedure has recently been launched to extend the lifetime of these units. In addition, there are plans to replace the old units with new ones. The parallel operation of the old and new units will be temporarily possible.

Gas- and coal-based generation also makes a major contribution to the national electricity supply, having accounted for over 20 per cent and 18 per cent of total electricity generation in 2016 respectively. The Mátrai Erőmű lignite-fired power plant is the second largest power plant in Hungary with 965 MW of installed capacity. Together with the Paks power plant, it accounted for 70 per cent share of electricity generation in the year 2016. Conversely, all renewable energy plants combined had a share of only slightly more than 10 per cent in electricity generation, with biomass and wind being the main pillars followed by biogas and hydropower. Solar power currently plays a minor role. However, its installed capacity has grown significantly in recent years.[4]

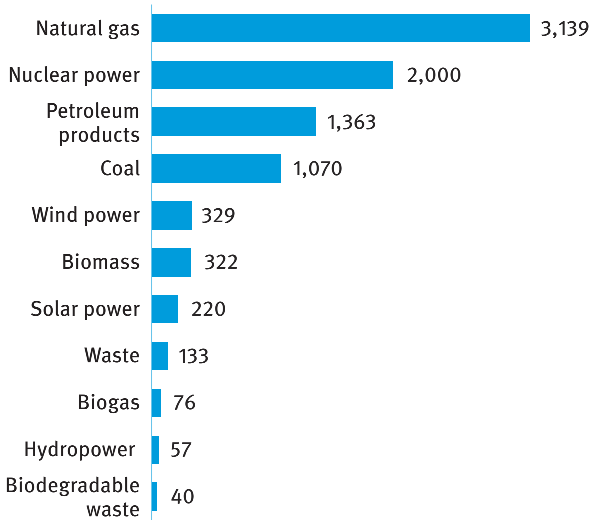
Figure 1.
Annual electricity generation by source in Hungary (GWh)



Source: HEA[4]

The installed capacity of Hungary at the end of 2016 was 8,479 MW, with 35.9 per cent coming from natural gas-fired power plants, 22.9 per cent from nuclear power, 15.6 per cent from oil-fired plants, 12.2 per cent from coal-fired plants, 3.8 per cent from wind power, 3.7 per cent from biomass, 2.5 per cent from solar power, 1.5 per cent from waste, 0.9 per cent from biogas, 0.7 per cent from hydropower and 0.5 per cent from biodegradable waste (Figure 2).[5,6] Thus, renewable energy sources accounted for slightly more than 12 per cent of the total installed capacity.

Figure 2.
Installed electricity capacity by source in Hungary (MW)



Source: HEA,[5] Eurostat[6]

The electrification rate in Hungary is 100 per cent, both in rural and urban areas.[10] In 2016, Hungary imported approximately one-third of consumed electricity.[7] It is expected that until 2030 electricity consumption will be growing at a rate of 1-1.5 per cent per year.[8] There is a need for new power plants mainly to replace the older ones, which have to be closed. A large-scale capacity expansion started after the European Commission approved funding for the Paks II nuclear power plant in early 2017. Two new reactors, each with an installed capacity of 1,200 MW, will replace the four reactors currently operating at the Paks plant, which were installed in the 1980s. The Paks II nuclear power plant is expected to start operation in 2026-2027.[9] The Government of Hungary considers the construction of Paks II necessary for replacing the phased-out generation capacity and reducing the country's import dependence.

As a member of the European Union (EU), Hungary had to adopt the EU rules on the single energy market, which include ownership unbundling, creation of a national regulatory sector and an Agency for the Cooperation of Energy Regulators. The liberalization of the Hungarian electricity market was completed in 2008. Today, power plants can be privately owned, producers can sell their electricity directly to customers or on the wholesale market and customers can freely choose a supplier, although the prices for universal suppliers are still regulated. As far as the European Union legislation is concerned, the application of the Third Energy Package has been carried out and the market competition has been constantly growing.[11] The main market regulatory body is the Hungarian Energy and Public Utility Regulatory Authority (HEA). Its main tasks are licence issue and ratification of the grid fees for transmission and distribution system operators.[12]

The only transmission system operator (TSO) in Hungary is the state-owned MAVIR, which operates the entire transmission system in Hungary according to the Independent Transmission Operators (ITO) model introduced by the Third Energy Package of the EU. Six distribution system operators (DSOs) are responsible for the distribution of electricity, of which one is state-owned and the others are private – E.ON South-Donau DSO, ÉMÁSZ DSO, E.ON North-Donau DSO, NKM Electricity Supplier DSO, ELMÜ DSO, and E.ON Tisza-region DSO. All of them are legally and functionally unbundled. Third party access to the grid is fully guaranteed on the whole territory of the country according to the requirements of the Third Energy Package. There is an intense competition on the electricity wholesale and retail electricity markets of Hungary, except for the residential segment where regulated prices are set for households and small enterprises.

The Hungarian power exchange, HUPX, operates an efficient, secure day-ahead, physical futures and intra-day power market. HUPX Day-ahead Power Market was launched in July 2010 as part of the liberalization of the Hungarian energy sector. Currently, 61 companies from 19 countries trust HUPX to define a transparent and reliable power price, which is used as a benchmark for the whole region as well as the Balkans.[13]

As of the end of 2016, the total length of the Hungarian transmission network was 4,856 km with 32 substations, and included 268 km of the 750 kV overhead lines, 2,978 km of the 400 kV overhead lines, 1,394 km of the 220 kV overhead lines, 199 km of the 132 kV overhead lines and 17 km of the 132 kV high-voltage cables. The total length of the distribution network was 161,634 km, which consisted of 6,356 km of the high-voltage overhead lines and cables, 67,811 km of the medium-voltage overhead lines and cables and 87,467 km of the low-voltage overhead lines and cables.[7]

Regulated electricity tariffs are set for residential customers and small-sized enterprises having access to the grid with a main fuse of up to 3 x 63 A. Gradual price cuts in this segment have been undertaken by the Government in recent years aiming to secure an affordable electricity price for all residential customers in Hungary. In theory, households can choose free market offers as well, but the only trader that offered free market contracts to residential customers returned its permission at the end of 2017.

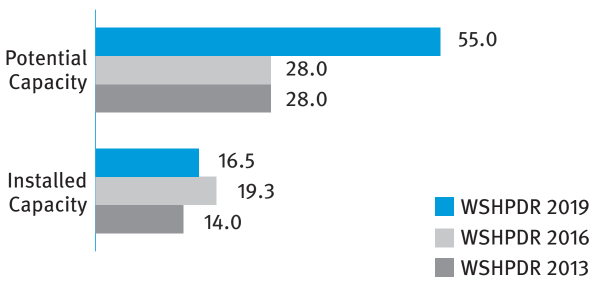
According to the recent comparison of residential customer prices in the European Union as of January 2018, the average price that a typical Hungarian household customer paid was 0.1206 EUR/kWh (0.14 US$/kWh), which was the third lowest in the EU.[14] It has to be mentioned, however, that in Hungary household customers do not bear the costs of supporting mechanisms for electricity from renewable energy sources (RES-E) at all.

As regards the wholesale market, the entire territory of Hungary is part of the same bidding zone including Czechia, Slovakia and Romania. As end-user prices are regulated, network costs remain the only component of the final electricity cost that varies to a small extent within the country depending on the geographic location of the distribution system operator. Each year the Hungarian Energy and Public Utility Regulatory Authority (HEA) determines the network tariffs for transmission and distribution and sets universal service prices for the Hungarian Government. In the course of fee monitoring HEA verifies whether the licensees actually apply the fees determined by the Government or by the regulator. During the cost review HEA determines the justified costs of the licensees, which serve as the basis for the official price setting.

Small hydropower sector overview

In Hungary, small hydropower (SHP) is defined as hydropower plants with an installed capacity of 5 MW or less. At the end of 2016, the number of SHP plants up to 5 MW in operation in Hungary was 28.[5] Their combined installed capacity amounted to 16.5 MW.[5] The average installed capacity of the 28 operational SHP plants in Hungary was approximately 0.6 MW. In 2016 these SHP plants produced 68.7 GWh of electricity.[5] Due to the relatively unfavourable natural conditions, the total hydropower potential in Hungary is rather modest. The technical potential capacity is estimated at 710 MW with an annual generation of 4,000 GWh, out of which the potential on smaller rivers (up to 5 MW) is estimated at approximately 55 MW with an annual generation of 300 GWh.[15] Compared to the results of the *World Small Hydropower Development Report (WSHPDR) 2016*, the installed capacity of small hydropower in Hungary decreased by almost 15 per cent, whereas potential capacity increased by 96 per cent – both due to access to more accurate data (Figure 3).

Figure 3.
Small hydropower capacities 2013/2016/2019 in Hungary (MW)



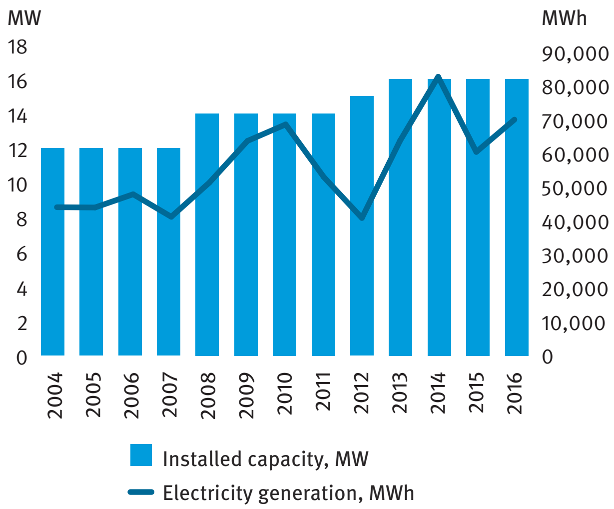
Source: HEA,[5] Hungarian Academy of Sciences,[15] *WSHPDR 2016*,[16] *WSHPDR 2013*[17]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

Hydropower has been utilized in Hungary for decades. The first hydropower plant was built in 1896 on the river Rába near Ikervár. The two SHP plants on the river Hernád (located near Gibárt and Felsődobsza) are also more than 100 years old. These plants are still running, some refurbishments have been performed and more are planned. Windmills were also converted into SHP plants at the beginning of the 1900s.

These 100-year-old hydropower plants constitute part of the culture of small villages. Thus, SHP plants have a long tradition of operation in Hungary, their operators are important local tax payers and supporters of local events. In general, the awareness of SHP is positive, with small hydropower plants being regarded as an environmentally friendly technology. The investment conditions and legislative environment also favour the development of SHP in the country. However, new investments in SHP plants are rare, which is mainly due to the modest natural conditions and the fact that the most suitable sites have already been developed. Furthermore, due to unfavourable natural conditions, investment costs are rather high, which explains the low number of new investments. Changes in the installed capacity and electricity generation of small hydropower plants in Hungary, according to Eurostat data, are shown in Figure 4.

Figure 4.
Installed capacity and electricity generation of small hydropower plants in Hungary



Source: Eurostat[6]

All hydropower plants in Hungary are connected to the electricity grid. The licensing process for SHP plants includes the receipt of an environmental permit, water rights permit, a building permit (which is a prerequisite for applying to the HEA for a small power plant licence) and a grid connection agreement from the DSO.

Electricity generation from renewable energy sources in Hungary is supported through the feed-in tariff system (the so-called KÁT-system) and the feed-in premium system (the so-called METÁR system). For SHP plants that had applied for support before 31 December 2016, a feed-in tariff is provided. As of 2018, tariff rates were 30.70 HUF/kWh (0.12 US$/

kWh) for hydropower plants below 5 MW and 18 HUF/kWh (0.07 US$/kWh) for hydropower plants above 5 MW.[18] Feed-in premium support within the METÁR system is available for the renewable electricity generating projects applying for support after 1 January 2017. Renewable electricity producers with an installed capacity of 1 MW and more take part in a technology-neutral auction scheme, with the supported price being determined through competitive bidding. SHP plants between 0.5 MW and 1 MW do not have to take part in the auction and can apply for a premium above the reference market price. The sum of the premium and the reference market price in 2018 was 31-32 HUF/kWh (0.12 US$/kWh) (floating premium). SHP plants of less than 0.5 MW applying for support after 1 January 2017 also receive a feed-in tariff (the so-called METÁR-KÁT), with the average tariff in 2018 being 30.70 HUF/kWh (0.12 US$/kWh).[19]

The feed-in tariff and premium are financed by industrial electricity consumers, while households are exempt. Investment support is available from EU structural funds according to the current calls. Eligible technologies, entitled entities, support amounts and rates vary according to the call. Preferential loans for renewable energy investments financed by EU structural funds are currently also available.

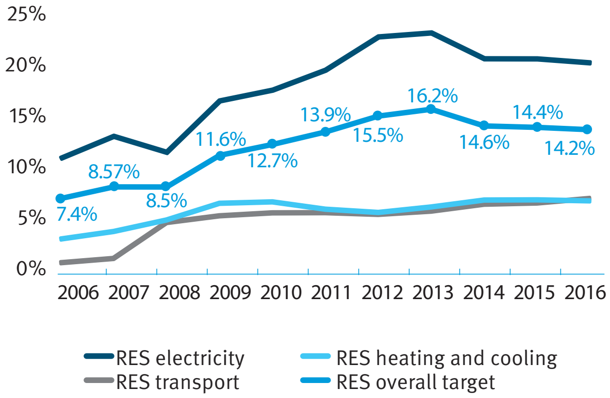
The Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) introduced trade in the greenhouse gas (GHG) emissions allowances, of which Hungary has a substantial quota surplus. The revenue accumulated from the sale of these allowances is used for climate protection purposes, including the promotion of renewable energy within the framework of the Green Investment Scheme (GIS). GIS supports the development of renewable energy as part of the investment in energy-saving measures.[20] Bank financing is also available, as banks see favourable conditions in renewable energy projects as generating stable revenues following the receipt of generation support. SHP plants under 50 kW are also supported under a net-metering regime.

Renewable energy policy

The Energy Strategy until 2030 and the National Renewable Energy Action Plan until 2020 (NREAP) are the basis of the Hungarian renewable energy policy. The binding target set for Hungary by the Renewable Energy Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources is a 13 per cent share of renewable energy in final energy consumption in 2020. The target set by the NREAP is slightly higher – 14.65 per cent.[21] The targets set for 2020 have almost been achieved, although further action is still needed in the transport sector to reach the 10 per cent share of renewable energy sources by 2020 (Figure 5).[6] Furthermore, the Energy and Climate Awareness Raising Action Plan (Government Decision 1602/2015) set the target of spreading awareness of energy and climate.[22]

Small hydropower is considered sustainable among the public and decision-makers. Conversely, large hydropower is not regarded as a feasible option compared to other sources of energy. Plans to build a pumped storage hydropower plant arise from time to time (mainly due to the expected favourable effects in balancing the electricity system), but due to not too favourable geological conditions, high investment costs and environmental concerns of the public, no plan has been realized so far.

Figure 5.
Sectoral and overall shares of energy from renewable energy sources in Hungary in 2006-2016 (%)



Source: Eurostat[6]

The Ministry of Innovation and Technology is the lead energy policy institution. It is responsible for conventional energy resources (crude oil, natural gas and coal), electricity and nuclear energy (except for capacity expansion at the Paks nuclear power plant). The Ministry is also responsible for renewable energy, climate policy, energy efficiency and related sustainability issues. The Ministry of Innovation and Technology also handles the greenhouse gas (GHG) emissions rights and is responsible for transport, including electromobility plans. The Office of the Prime Minister is the project owner of the capacity expansion at the Paks nuclear power plant. The First National Public Utility Holding Company operates under the supervision of the Office of the Prime Minister. The Ministry of Foreign Affairs and Trade is responsible for the energy security and diplomacy. The Ministry of Agriculture is responsible for collection, storage and processing of GHG emissions data by means of the National Meteorological Service.

The Hungarian Energy and Public Utility Regulatory Authority is an independent agency responsible for reporting statistics (energy and stocks), exercising regulatory oversight in electricity, natural gas, district heating, water utility and waste management. It determines network usage and access charges and issues relevant permits. The Hungarian Atomic Energy Agency exercises regulatory oversight over nuclear facilities.[20]

Barriers to small hydropower development

The development of large-scale hydropower in Hungary has been a much-debated topic, mainly due to the controversial Gabčíkovo–Nagymaros Dams project with Slovakia on the river Danube. Large hydropower is still not considered as a real option compared to other sources of energy. Moreover, a significant part of the country has a flat terrain, with only some low hills. As a result, rivers with high water output do not have marked drops in elevation. Therefore, small-scale hydropower is considered as a more feasible technology compared to the large plants.

No major barriers to SHP development in Hungary have been identified. However, as the most suitable sites have already been developed, no significant development in the SHP sector is currently expected.

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4.1.5 Republic of Moldova

Nicolae Soloviov, Energy Efficiency Agency Moldova

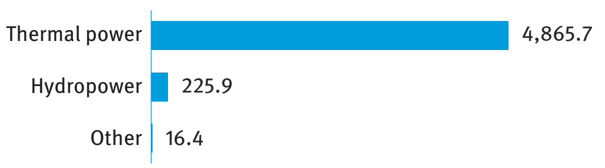
Key facts

Population	3,550,900 [1]
Area	33,851 km^2 [2]
Climate	The Republic of Moldova is located in the temperate-continental climate zone. The average annual air temperature from north to south ranges between 8 °C (Briceni) and 10 °C (Cahul). Winter in the Republic of Moldova is mild with an average temperature in January estimated between -5 °C and -3 °C. The temperature can drop to -15 °C and even to -20 °C. The summer is warm and long-lasting. The temperature in July varies from 19.5 ° to 22 °C. Summer rains are often short and abundant, sometimes causing local flooding. Autumn is warm and long. In November, the average temperature drops reaching between 3 °C and 5 °C.[4]
Topography	The relief of the Republic of Moldova is fragmented, characterized by a succession of relatively low plateaus and plains. The average altitude is 147 metres. The maximum is reached at Bălăneşti Hill at 429.5 metres and the minimum - about 2 metres - in the lower course of the Nistru river. The northern part of the country is occupied by the Moldavian Plateau, with altitudes varying between 240 and 320 metres. In the south of the country lies the South Moldavian Plain with large valleys and dissected ravines. The maximum altitude of the South Moldavian Plain is 247 metres.[4]
Rain pattern	The territory of the Republic of Moldova belongs to the area with insufficient humidity. The amount of rainfall decreases from northwest to southeast, from 620 mm to 490 mm during the year. Precipitations fall mainly in the warmer period of the year in the form of rain showers, and only about 10 per cent of the annual amount is snow.[3]
Hydrology	The river basin of the Republic of Moldova is represented by 3,621 rivers and streams with a total length of about 16,000 km. The longest rivers are Dniester, Prut, Raut, Bac, Botna, Ichel, Cogalnic and Lalpug. The largest flow of rivers is recorded in the spring, when the snow melts. The cross-border water resources of the Dniester and Prut rivers represent on average 90 per cent of the total water resources of the country.

Electricity sector overview

The domestic electricity production of the Republic of Moldova covers less than 20 per cent of the demand, while the rest is imported. The main reason for the high costs associated with electricity is the dependency of the country on natural gas, coal and oil imports. At the end of 2016, the total electricity production was approximately 5,108 GWh. Figure 1 below offers information with regards to the electricity generation by source in the Republic of Moldova.

Figure 1.
Annual electricity generation by source in the Republic of Moldova (GWh)



Source: Gherman Legal PLLC [19]

Total installed capacity in 2016 was 3,001 MW. Thermal power plants continue to dominate the electricity production sector. Figure 2 below offers more information on installed electricity capacity by source.

Figure 2.
Installed electricity capacity by source in the Republic of Moldova (MW)

Source: Gherman Legal PLLC[19]

The total electricity distributed was 3,622 GWh, out of which 1,636 GWh went to the residential sector.[18] Table 1 below details how much electricity was delivered to the grid by each power plant in the Republic of Moldova.

According to data on the dynamics of energy flows in the grid, in 2016, the distribution system operators and final suppliers have purchased 4,035.7 GWh, 0.4 per cent less than in 2015.

Table 1.
Delivery of electricity to the grid in 2016

Plant Name	*Plant Type*	*Installed power (MW)*	*Delivery of electricity to the grid in 2016 (GWh)*
CERS Moldavscaia	Thermal	2,520	4,170.397
CET-2 Chisinau	Thermal	240	607.322
Other sources	Diverse	87	16.371
CET-1 Chişinău	Thermal	66	33.311
CHE Dubasari	Hydropower	48	187.263
CET Bălți	Thermal	24	54.631
CHE Costești	Hydropower	16	38.619
Import from Ukraine			3.701
Total		**3,001**	**5,111.62**

Source: Gherman Legal PLLC[19]

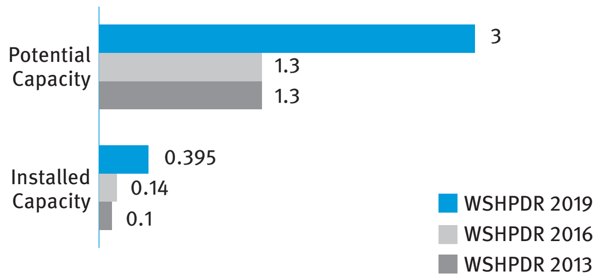
According to the energy balance data for 2016, the residential sector consumed most electricity in Moldova, followed by the commercial and public services sector. The average electricity price for standard consumer households at the end of 2016 was 1.94 MDL/kWh (excluding all taxes, dues and VAT), or about 0.0971 US$/kWh. The average electricity price for standard groups of final users from the industry at the end of 2016 was 1.88 MDL/kWh (excluding all taxes, dues and VAT), or about 0.0941 US$/kWh.[7]

Small hydropower sector overview

At present, only one small-scale hydropower plant in Moldova is functional, SRL Hidroelectrica. Its capacity is 254 kW and the tariff for delivery to the grid is 1.99 MDL/kWh (0.12 US$/kWh). In addition, six micro-hydropower plants built by individual producers and economic agents were identified. All small generating units are installed on the existing dam reservoirs, their combined capacity is 141 kW. As this report uses the definition of small hydropower as plants up to 10 MW, these six hydropower plants will also be considered.[18] The increase in small hydropower installed capacity compared to the *World Small Hydropower Development Report (WSHPDR) 2016* can be explained by data recently made available. After assessing all potential sites, only 3 MW of potential was discovered for plants up to 10 MW. Figure 3 below offers more information on the SHP installed and potential capacity in Moldova. The best potential for the development of hydropower plants is provided by small capacity plants. The river basin of the Dniester and Prut offers this development potential.

It is worth mentioning that during the Soviet Union period there were 17 small hydropower plants built on the small rivers of the Republic of Moldova, which used the potential energy of water on the rivers Raut, Bic, Ialpug, Cubolta, Racovat, Ciuhur, Vilia, Cainari, Lopatnic. At the moment, all of these SHPs are destroyed or damaged, and none are functional.[14] Until 2014, electricity from the hydropower sources was produced only by small-scale hydropower plants. The maximum annual contribution of the existing small hydropower plant is 81 MWh and it is expected that on average the plant will produce this annual energy volume by 2020. Currently there are no off-grid plants in the Republic of Moldova.[18]

Figure 3.
Small hydropower capacities 2013/2016/2019 in the Republic of Moldova (MW)



Source: *WSHPDR 2013*,[11] Energy Charter Secretariat,[14] EEA Moldova,[18] *WSHPDR 2016*[21]

Note: The comparison is between data from *WSHPDR 2013, WSHPDR 2016* and *WSHPDR 2019.*

Although there is a large number of rivers in Moldova, the potential for energy production by SHP is relatively small. At present, hydroelectric power is produced in the Republic of Moldova by the medium hydropower plants HPP Dubasari, with an installed capacity of 48 MW, and HPP Costești - Stinca 16 MW, totalling 64 MW. The Hydroelectric Power Plant Dubasari was built between 1951-1954 after a project by the "Ucrhidroproiect" Institute in Kharkiv. Currently, this power plant is outside of the central authorities' management and is located outside of the internal electricity generation of Moldova. In 1971, the Agreement between the Government of the Soviet Union and the Government of Romania on the joint construction of the Stînca-Costesti Hydro-Node on the Prut River was concluded. The works began in 1973. The plant was officially inaugurated on November 4, 1978 and the final reception was in 1979.

Renewable energy policy

In the Republic of Moldova, the renewable energy sector has a slow but positive dynamic. Under the conditions of the economic situation, the diversification of energy sources is a primary objective for the economic development of the Republic of Moldova. The European Union (EU) is developing an increasingly close relationship with the Republic of Moldova, going beyond cooperation, to gradual economic integration and a deepening of political cooperation. This fact indicates that the eventual adoption of EU legislation in the energy sector is a necessity.

In 2017, at the National Agency for Energy Regulation of the Republic of Moldova (ANRE) 48 companies that produce electricity using renewable energy sources in Moldova were registered, of which: 6 wind, 35 solar, 5 biogas and 2 hydropower, including the functional small hydropower plants of 0.395 MW installed capacity.[22] Total installed capacity in 2017 was 17,249 kW of which: wind 8,890 kW, solar 2,063 kW, biogas 4,442 kW and hydropower 1,854 kW.

Table 2.
Renewable energy deployment in the Republic of Moldova

Renewable energy shares [%]	*2009*	*2014*	*2020 (NREAP*)*
Gross final energy consumption (GFEC)	11.9	14.9	17
Electricity consumption	1.75	1.8	10

Source: MIEPO[12]

Note: *National Renewable Energy Action Plan (NREAP).

In 2017 the average tariff for renewable energy provided to the grid was 1.84 MDL/kWh (0.111 US$/kWh) for biogas, 1.11 MDL/kWh (0.067US$/kWh) for hydropower, 1.87 MDL/kWh (0.113 US$/kWh) for solar, and 1.18 MDL/kWh (0.071 US$/kWh) for wind.[8] Table 3 below offers information on the installed capacity of renewable energy in 2018.

Table 3.
Renewable energy installed capacity in the Republic of Moldova, 2018

Type of source	*Installed capacity (MW)*	
	*E-RES**	*H&C-RES***
Wind power	27.14	
Hydropower (no pumping)	16.25	
Solar PV	2.92	
Biomass total		155.35
Public sector		87.71
Residential sector		67.54
Biogas	5.71	
Total	**52.02**	**155.35**

Source: EEA Moldova[20]

Note: *E-RES - renewable electricity.

**H&C-RES - renewable energy used for heating and cooling purposes.

The State Energy Policy for Renewable Energy is implemented through the sectoral and local government programmes. The implementation of these policies is monitored by the central specialized body of the public administration in the energy field.[9] So far, significant progress has been made in implementing the provisions of the National Energy Efficiency Programme 2011-2020, the National Energy Efficiency Action Plan for 2013-2015, the Energy Strategy of the Republic of Moldova 2030 and the National Action Plan for Renewable Energy for the 2013-2020.[10] Numerous legislative and regulatory documents have been developed or updated, some of which have already been adopted:

- Law no. 44 of 27 March 2014 on the labelling of energy-related products, which entered into force in October 2014;
- Law no. 92 of 29 May 2014 on thermal energy and the promotion of cogeneration, which entered into force in July 2014, are repealed;
- Law no. 128 of 11 July 2014 on the energy performance of buildings, which entered into force in January 2015;[12]
- Law no. 151 of 17 July 2014 on eco-design requirements for energy-related products, which entered into force in April 2015;
- Law no. 107 of 27 May 2016 on electricity;
- Law no. 10 of 26 February 2016 on the promotion of the use of energy from renewable sources. This law creates the necessary framework for the implementation of 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, amending and subsequently repealing Directives 2001/77/EC and 2003/30 / EC, published in the Official Journal of the European Union no. L 140 of 5 June 2009.[10]

There are multiple support schemes and measures to promote renewable energy dissemination in the country:

- Fixed prices: for producers who currently own or will own power plants with a power greater than the cumulative capacity limit set by the Government;
- Fixed tariffs: for producers who currently hold or will hold power plants with cumulative power capacity not exceeding the limit set by the Government and not less than 10 kW;
- Net metering: for small renewable energy sector investors oriented on covering the own electricity consumption;
- Unregulated market: any other kind of legal relationships between a project developer and electricity supplier is allowed to be ruled in accordance with the principles and conditions negotiated directly by the two parties (protection facilities must be installed).[20]

In March 2018, the "Law on the promotion of the use of energy from renewable sources", which 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, entered into force.

Table 4.
Capacity limits, maximum allowances and capacity categories for support schemes

Technology	*Total*	*Fixed tariff approved by ANRE*	*Fixed price established by tender*	*Capacity limit (MW)*
Wind power	100	20	80	2
Solar PV	40	15	25	1
Biogas	20	12	8	1
Cogeneration (on solid biomass)	5	5	-	1
Hydropower	3	3	-	1
Total	**168**	**55**	**113**	-

Source: EEA Moldova[20]

Barriers to small hydropower development

Conventional energy, having been cheap for a long period of time, has become an obstacle to the development of renewable energy in Moldova. The barriers for the implementation of small hydropower projects are the following:

- Financial barriers: the lack of long-term funding, the initial cost of capital, the provision of financing as well as the pledged collateral;
- Access to technologies: lack of the local market technologies, the need to import them and the high costs of imported technologies;
- Technical capabilities and experience: limited overall technical experience, lack of technical skills;
- Lack of a reliable technology or standardized concepts: each installation needs to be individually designed, which results in high engineering costs and increased initial investments;
- Interconnection to the electricity network: Interconnection processes can be costly and time-consuming, which can lead to investment losses.

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4.1.6

Poland

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

Key facts

Population	38,422,346[1]
Area	312,679.67 km[2]
Climate	A border between 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, and the warmest month is July, with average temperatures between 16.5 °C to 18.5 °C. The number of days with temperatures below 0 °C ranges between 90 and 130, though is over 200 days in the mountains. The number of days with temperatures above 25 °C ranges between 5 and 40.[2]
Topography	Poland is a lowland country with majority of its land located at lower than 300 metres above sea level. The highest point is 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 is in its northern border and the ridges of the Carpathian Mountains and the Sudetes constitute its southern border.[2]
Rain pattern	The amount of precipitation depends on the region. The highest is 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, the majority occurring in summer months. [2]
Hydrology	About 99.7 per cent of Poland belongs to the Baltic Sea drainage basin, which in turn is 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 on the east of the Vistula and Oder Rivers, mainly because of its topography slopes towards the north-west. The longest rivers are the Vistula (1,047 km), the Oder (854 km), the Warta, (808 km) and the Bug (772 km). Poland has approximately 9,300 lakes larger than 0.01 km[2] which altogether cover 3,200 km[2] (approximately 1 per cent of the country) and have a capacity of 17.4 km[2].[3]

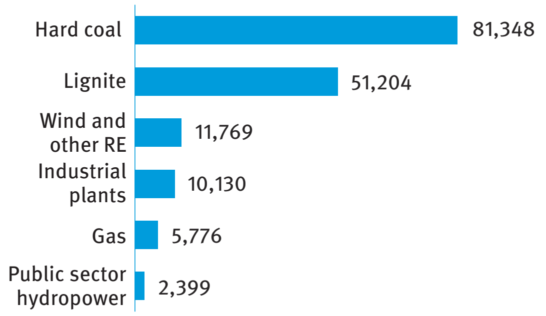
Electricity sector overview

At the end of 2016, the installed capacity in the Polish National Electricity System was 41,396 MW.[3] Total gross electricity generation was 162,626 GWh and gross electricity consumption was 164,626 GWh.[4] A great majority of generation is still based on conventional fuels, that is hard coal and lignite which contributed 82 per cent of total gross electricity generation in 2016 (Figure 1).

Renewable energy accounted for 8,538 MW and its share in the total installed capacity increased from 16 per cent in 2014 to nearly 21 per cent in 2016 (Figure 2).[4]

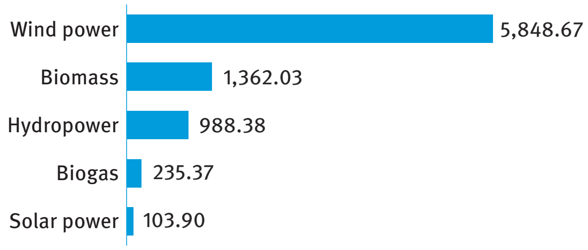
In 2016, renewable energy sources accounted for 13.4 per cent of the gross electricity consumption.[5] The electrification rate and grid availability in Poland is 100 per cent. The number and structure of electricity generating plants have not changed significantly in comparison to 2014. In 2016 three companies, Polska Grupa Energetyczna S.A., TAURON Polska Energia S.A. and ENEA S.A., owned more than 50 per cent of installed capacity, and provided nearly 60 per cent of the total electricity generation and 55 per cent of the energy fed into the grid.[4] Most of the Polish power companies continue to be owned by the State Treasury.

Figure 1.
Annual electricity generation by source in Poland (GWh)



Source: Energy Regulatory Office (URE)[4]

Figure 2.
Installed renewable energy capacity by source in Poland (MW)



Source: Energy Regulatory Office (URE)[4]

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 transmission grid, consisting of 257 lines of a total length of 14,123 km, 106 extra high voltage stations, 1 provisional (portable) line as well as a submarine 450 kV DC link between Poland and Sweden (254 km long).[6]

According to the EU energy market legislation, Poland is implementing the principle of unbundling energy suppliers from network operators. At the end of 2016 there were 172 distribution system operators involved in the electricity distribution, including five entities legally separated from the former distribution companies, out of which four operate within groups which are vertically integrated energy companies, whose majority of shares belong to the State Treasury.[3]

End users are entitled to receive electricity from a chosen supplier uninterruptedly and reliably. In 2016 there were five default suppliers and over 108 alternative trading companies actively selling electricity to final consumers.[4] There are four electricity tariff groups in Poland. Groups A and B are for the industrial users (supplied on the high and medium voltage grids), group C is for the commercial users (connected to the low voltage grid) and group G is for the residential users. In 2016, there were 17.24 million consumers in the retail electricity market (increase by 14.93 per cent compared to 2014) out of which 90.6 per cent are in the G tariff group.[4] The prices for companies using tariffs A, B and C are not regulated as of 2008 while the G tariff (for households) remains the only one regulated.[3] In the last quarter of 2016, the average price of electricity in the retail market increased by 2.6 per cent as compared to the last quarter of 2014 and amounted to 459,8 PLN/MWh (136.04 US$/MWh), of which PLN 262.4 (US$ 77.63) constituted the price of energy and PLN 197 (US$ 58.40) constituted the distribution fee.[4]

The Polish Energy Regulatory Office, which is an independent agency, is responsible for the regulation of the electricity, gas, and heating markets including licensing, approving investment plans by regulated companies, deregulation of the electricity and gas markets, oversight of the quality of supply and customer service, and setting the tariffs.[3]

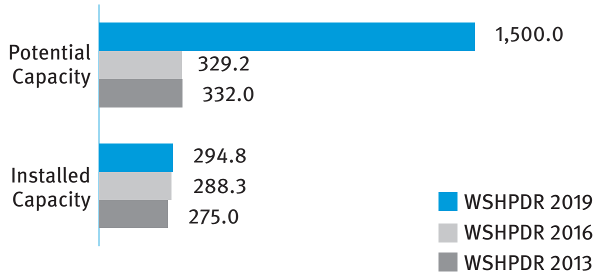
The Polish energy sector requires substantial investments, as confirmed by the average age of existing power plants. Almost 40 per cent of the power blocks are over 40 years old and 15 per cent of them are over 50 years old.[7] The biggest projects in energy sector completed since 2016 include a new 1,075 MW unit of a coal-fuelled power plant Kozienice and four gas-fuelled plants of a total installed capacity 1,267 MW. Currently, plants with a capacity of 19 GW are being planned or built mainly using coal, gas, and the nuclear power. This also includes one large hydropower plant on the Vistula river with a capacity of 80 MW and the country's first nuclear power plant.[8]

Small hydropower sector overview

There is no official definition of small hydropower (SHP) plants in Poland. However, installations with a total capacity of no more than 5 MW are customarily included in this category.[10] This differentiation is also partially reflected in the Act on Renewable Energy Sources (Act on RES), according to which hydropower plants with a capacity up to 5 MW are currently entitled to receive "green certificates".[11] However, the Act on RES also includes other size-dependent regulations, such as separate auctions and prices for installations with a capacity not exceeding 1 MW, as well as some simplified rules for renewable energy facilities defined as "small installation" with a capacity limit of 200 kW.[11]

In 2017, Poland had 766 hydropower plants, out of which 756 were up to 10 MW.[12] The total installed capacity of hydropower plants in Poland was 988.4 MW out of which 294.8 MW was the installed capacity of small hydropower plants (up to 10 MW) indicating that SHP plants up to 10 MW represented 29.8 per cent of the total hydropower capacity corresponding to 2.2 per cent increase in comparison with the *WSHPDR 2016* (Figure 3).[12,33] In 2016, electricity generation from SHP (up to 10 MW) was 908 GWh. [5]

Figure 3.
Small hydropower capacities 2013/2016/2019 in Poland (MW)



Source: *WSHPDR 2013*,[32] *WSHPDR 2016*,[33] ESHA,[14] Energy Regulatory Office[12]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

In addition to the developed capacity, in 2017, 162 SHP projects (up to 10 MW), with a total capacity of 55.97 MW and an expected annual generation of 252 GWh, were under construction or in the process of obtaining permits.[13] It is estimated that these projects could be finalized by 2030. Thus, the total potential capacity expected to be developed by 2030 is estimated to be around 350.72 MW for plants up to 10 MW, indicating that 88 per cent has been already installed. In addition to that, the technically feasible potential capacity, which could be developed over a longer timeframe, is estimated to be much higher.[14] 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.[16,17] Out of this, the technical hydropower potential for SHP plants (up to 10 MW) in Poland is estimated to be approximately 5 TWh/year, corresponding to at least 1,500 MW of potential installed capacity.[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.[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 allocated in the lower Vistula region and 17.6 per cent of resources in the Oder River basin. The rivers with the largest hydropower potential are the Vistula, Dunajec, San, Bug, Oder, Bóbr and Warta. Regions most favourable for the hydropower development are southern parts of Poland (mountain area) as well as western and northern parts (due to the existing hydro infrastructures).[16]

In the 1920s and 1930s, there were over 8,000 hydropower facilities in Poland (many types of mills and some hydroelectric power plants).[18] Only 2,131 installations remained by 1980s and only 300 were in use at that time.[17,19] The possibility of repowering these historic sites is indicated as the potential for economically feasible and environmentally sustainable small and micro hydropower generation both by the Government and non-governmental organizations In the Energy Policy of Poland until 2030 as well as in the Addendum To The National Action Plan For Energy From Renewable Sources,[20] utilization of the existing state-owned damming structures for electricity generation is listed as one of the aims. To meet this objective, the National Water Management Authority took an inventory of the damming structures.[21] The results showed that there are more than 14,000 dams and weirs (with minimum head of 0.7 m) out of which only 4.5 per cent is used for electricity generation. Another database, the RESTOR Hydro Map, created within the Intelligent Energy Europe Programme of the European Union, identifies 8,000 historical mills sites as a potential micro and small hydropower plants locations.[22]

The licensing process for SHP in Poland consists of several steps.[23] Firstly, the environmental impact of the development needs to be considered and the environmental decision needs to be obtained. Furthermore, the decision on building conditions is necessary and issued by the local administration unless, in rare cases, there is a spatial development plan covering the investment area. A water-legal consent and water-legal assessment needs to be gained from the water authority. The next important stage is to acquire the rights to manage the real estate being property of the State Treasury (i.e. lands covered with running water and most probably the weir) from the water authority which is responsible for maintenance and ownership supervision over the estate. The finishing juncture of the procedure is to acquire a permit for erection through an application to poviat or voivodship authority. Apart from the above decisions, to start operating a power plant a decision on terms and conditions of grid connection, and subsequently a grid connection agreement is required from the system operator (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 renewable energy source from the Energy Regulatory Office will be needed for plants with the installed capacity exceeding 200 kW. Plants with the capacity between 40 and 200 kW must be only entered in the register of electricity producers in small installations also run by the Energy Regulatory Office while micro producers (in installations up to 40 kW) need to notify the local system operator about their plan to start generation only.

The development of new projects has been straitened in the last few years due to the collapse of the green certificate system and a gap between closing of this support system and starting the new one (auctions).[11] As a result, since the 1 July 2016 there has been no option to commission a new hydropower plant within any support scheme.

European funds played a significant role in SHP development in Poland between 2007 and 2013.[23] The financial perspective for 2014–2020 opened new financial potential. Projects related to the development, reconstruction and modernization of the renewable energy sources are planned for every operational programme. However, some restrictions included in the documents turned out to prevent SHP projects from receiving financing. For example, the requirement that co-financed projects have to be listed in documents resulting from the Water Framework Directive implementation in Poland.[24] Operational programmes are mostly dedicated to local government units and entrepreneurs. Other funding options come from the National Fund for Environmental Protection and Water Management, the Regional Funds for Environmental Protection and Water Management, Norway grants (within the Green Industry Innovation Programme for Poland), the Rural Development Foundation and commercial banks.

It is worth noting that due to the problems of green certificates oversupply, with their prices falling from over PLN 251.21 (US$ 65.55) per MWh in 2012 to PLN 36.47 (US$ 48.09) in 2017, commercial entities strengthened their requirements, increased the loan rates for new offerings, asked for additional loan collateral, stopped renewable energy financing and examined the financing applications of all projects.[23,25]

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 the carbon-intensive fossil fuels and development of the renewable energy sources do not play a significant role for decision-makers. At the European Union level, Poland continuously opposes more ambitious greenhouse gas reduction targets and further developments of climate change policies.[26]

The main energy policy objective in the field of renewable energy sources, and the country's binding target from the EU 2020 Climate and Energy Package, is to increase the share of renewable energy sources in total energy consumption to at least 15 per cent in 2020, and further increase it in the following years. So far, in 2016 Poland reached 11.3 per cent share of energy from renewable sources (including electricity, transport, heating and cooling sectors) in gross final energy consumption.[5] Poland's intended path to meet its 2020 targets is outlined in the National Renewable Energy Action Plan.[20]

On 16 November 2017 the European Commission presented the Clean Energy for All Europeans proposals which, according to the Ministry of Energy, will imply the work on Energy Policy of Poland until 2050. This long-awaited document should determine long term vision for energy sector in Poland. Until then the Energy Policy of Poland until 2030 adopted in 2009 is the main energy-specific long-term strategy in force.[9]

Another strategic document which indicates the main directions of the country's development, including those of the energy sector was adopted in 2016.[27] In the Strategy for the Responsible Development, increasing the use of hydropower potential and hydropower sector development was classified as one of the projects to be implemented. This objective should be achieved by means of „liquidation of administrative barriers constricting hydropower investments, development of hydropower equipment manufacturers industry as well as utilisation and refurbishment of existing, State-owned damming facilities for the purpose of hydropower generation".[27]

Since 2004 the support schemes for renewable energy have been based on a quota system.[28] Renewable energy producers who joined this system by 1 July 2016 are supported in two ways: first, they have the possibility of obtaining tradable green certificates; second, there is an obligation of purchase for electricity by the appointed energy entities, with a price announced quarterly by the Energy Regulatory Office and based on the average electricity sales price on the competitive market. Since mid-2012, this system has been destabilized mainly due to the oversupply of certificates causing the value of green certificates to decrease from PLN 251.21 (US$ 65.55) per MWh in 2012 to PLN 36.47 (US$ 48.09) in 2017 and electricity price within the obligation of purchase to decrease from PLN 198.90 (US$ 51.90) per MWh in 2012 to PLN 169.70 (US$ 50.21) in 2016.[25,29]

On 20 February 2015, the Act on RES was adopted in Poland introducing a support scheme based on tendering (auctions).[11] In the new scheme, the reference (maximum) prices are defined for each technology and additionally within technology for installations with capacity up to 1 MW and above. Auctions are conducted separately for existing and new installations with the capacity division up to 1 MW and above. The producers who win the tender have the right to receive the offered price for 15 years. The act came into force on 5 May 2015, but the date of coming into force of the 4th chapter which included the support mechanisms for producing renewable energy was postponed, initially until 1 January 2016 and finally until 1 July 2016. Another amendment to the RES Act dated 22 June 2016 introduced numerous changes in the support mechanisms for micro-producers (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.

Several auctions were carried out according to the new rules in 2016 and 2017, including two auctions for installations with productivity above 3,504 MWh/MW/year and with CO_2 emission level up to 100 kg/MWh, where 93 offers from SHP producers won contracts and were able to migrate from the certificate system to the system of guaranteed prices.[30] There are no Feed-in Tariffs (FIT) or Feed-in Premium (FIP) in Poland at present, however, there is a draft amendment to the Act on RES which intends to introduce FIT and FIP for SHP and biogas installations in 2018.[15]

Other legal acts impacting the SHP sector which came into force recently are the Water Basin Management Plans (WBMP) adopted on October 18, 2016 and the new Water Law adopted on July 20, 2017. The Water Law, entirely reformed water administration and management by introducing catchment-based approach and the State Water Holding "Polish Waters", introduced fees for the water use in the hydropower sector (PLN 1,24 (US$ 0.37) per each MWh of electricity generated in a hydropower plant) and rules of enabling investors utilization of state-owned weirs through tenders, with certain exceptions.[31] WBMPs and Conditions of Water Use in Water Regions (i.e. local legal acts adopted in each water region) comprise requirements for the residual flow, fish migration and restrictions in developing new hydropower projects which have to be consistent with the EU Water Framework Directive.

More than 80 per cent of the technical SHP potential generative capacity in Poland remains unused due to historical circumstances and various administrative barriers but also due to its specific nature. Both the governmental inventory and the RESTOR Hydro project outcomes prove the need for adaptation of existing weirs and for making use of sites characterized by very low heads and small flows. According to the SHP sector this goal can only be achieved with stable financial conditions and effective regulations giving investors access to SHP sites. However so far none of these two conditions has been observed. Continuously changing legal conditions make a challenge both for SHP investors and operators. The reduction of prices of green certificates has been very perceptible for renewable energy producers, nevertheless, very few hydro producers have decided to give offers in tenders and switch from the certificates to auction system, which is regarded as very risky, complicated and not appropriate for small producers. Thus, the SHP sector awaits the draft amendment to the Act on RES which intends to introduce FIT and FIP for SHP installations in 2018 and expects effective management of State-owned weirs by newly established "Polish Waters".

Barriers to small hydropower development

The key barriers are:

- Legal uncertainty preventing form developing new investments;
- No guarantee of support and its unknown level at the permitting and prearrangement stage;
- Inadequacy of the current support schemes (auctions) for small hydro producers (i.e. complicated procedures, strict penalties, auction criteria of productivity, long time gaps between auctions);
- Financial difficulties with upkeeping of the existing plants:
    i. The slump in the green certificates market;
    ii. Increase of the operational cost of SHP due to the obligation to adapt the facilities to more and more rigorous environmental requirements (building fish passes and fish barriers, increasing residual flow, etc.);
    iii. Implementation of the water pricing for hydropower since 2018;
    iv. Expected increase of fees paid already for using dams and lands covered with water owned by the State;
    v. Threat of profitability loss after operational support period.
- Impossibility of regaining support after refurbishment according to the present law regulations;
- Use of the installed capacity criterion in granting support instead of power generation capacity criterion which discriminates hydropower plants with reservoirs designed for providing services for the energy system;
- Constrains preventing financing hydropower investments from the EU Funds;
- Lack of effective and common regulations allowing utilization of existing weirs for hydropower purposes;
- Lack of spatial development plans in which SHP projects would be included.

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4.1.7

Romania

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Key facts

Population	19,942,642[1]
Area	238,391 km[2]
Climate	Romania has temperate continental climate with four seasons, typical for Central Europe. Cold, cloudy winters with frequent snow and fog; sunny summers with frequent showers and thunderstorms.[2] The average temperature ranges from 10 °C and -11 °C in the South to 8.5 °C and -9°C to the North. The maximum average temperatures during summer are 22 °C to 24 °C and during winter are between -3 °C and -5 °C.[3]
Topography	Romania's landscape is almost evenly divided among mountains (31 per cent), hills (33 per cent), and plains (36 per cent). These forms of relief spread rather evenly from the Carpathian Mountains, which reach elevations of more than 2,400 metres, to the Danube Delta, which is just a few metres above sea level.[4]
Rain pattern	Rainfall, although adequate throughout the country, decreases from west to east and from mountains to plains. Some mountainous areas receive more than 1,010 mm (39.8 in) of precipitation each year. Annual precipitation averages about 635 mm (25 in) in central Transylvania, 521 mm (20.5 in) at Iași in Moldavia, and only 381 mm (15 in) at Constanța on the Black Sea.[5]
Hydrology	The most important river of Romania is the Danube. Its lower course forms a delta that covers much of northeastern Dobruja. Most of Romania's major rivers 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, but the largest lakes are saline lagoons on the coast of the Black Sea. The largest of these is Lake Razelm.

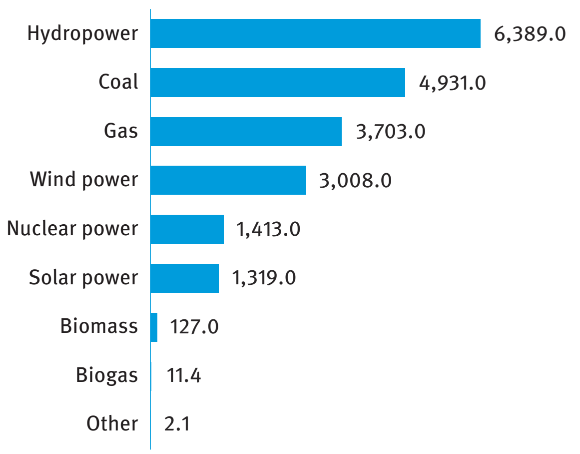
Electricity sector overview

The installed electricity generation capacity in Romania in 2017 was 23,738 MW, while the available capacity was approximately 20,891 MW, mainly due to the ageing equipment. Electricity generation by source is as follows – hydropower (24.1 per cent), coal (26.4 per cent), nuclear (18.4 per cent), gas (16.8 per cent), wind (12.7 per cent), solar (1.4 per cent), biomass (0.2 per cent).[6]

The available installed capacity in 2017 was – nuclear 1,413 MW, coal 4,931 MW, hydropower 6,389 MW (of which SHP – 404 MW) gas 3,703 MW, wind 3,008 MW, solar 1,319 MW, biomass 127 MW (Figure 1).[6] In 2017 the total electricity generation was 61.3 GWh, compared with 61.8 GWh in 2016. These numbers were taken from the data collected by the National Regulatory Agency.[6]

The National Grid is developing and was challenged by the fast development of wind energy and photovoltaic energy concentrated in the south-eastern and eastern areas of the country, wind energy development was especially noticeable in Dobrogea region. Due to this rapid development, the grid access is completely denied for new power plants. The promotion scheme with green certificates (GC) for Renewable Energy Sources ended at the end of 2016, therefore in 2017 no new installations could benefit from the GC scheme.

Figure 1.
Installed electricity capacity by source in Romania (MW)



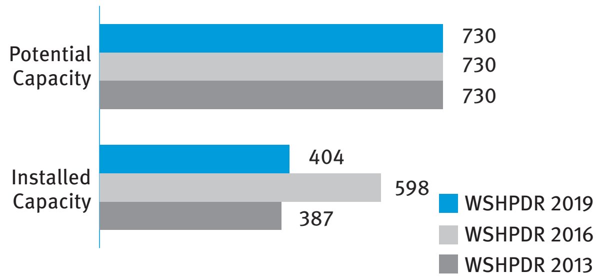
Source: National Energy Regulatory Agency[6]

The distribution activity is organized in several zones which were subject to privatisation – Banat (Enel), Transilvania Nord (Electrica), Transilvania Sud (Electrica), Oltenia (CEZ), Muntenia Sud (Enel), Muntenia Nord (Electrica), Moldova (E.On) and Dobrogea (Enel). The Government regulates transmission and distribution tariffs for every region. These tariffs are differentiated on the voltage level of the end consumer and do not consider whether the consumer is industrial type or a household. The tariffs are subject to yearly regulation and are updated by the Romanian National Regulation Agency.

Small hydropower sector overview

Romania's definition of small hydropower is up to 10 MW. In 2017 the installed capacity of small hydropower in Romania was 404 MW (342 MW and 62 MW refurbished) while the potential capacity is estimated to be 730 MW indicating that approximately 55 per cent has been developed. Between the 2016 and 2019 *World Small Hydropower Development Reports* installed capacity has decreased due to better assessment of total installed capacity while the potential capacity has not changed.

Figure 2.
Small hydropower capacities 2013/2016/2019 in Romania (MW)



Source: *WSHPDR 2013*,[10] *WSHPDR 2016*,[11] Romanian Energy Regulatory Agency[6]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

Pumped storage hydroelectric power plants are not considered renewable energy sources and are not included in the Renewable Energy promotion scheme with green certificates. In 2017, hydropower accounted for about 24.1 per cent of the total energy generation in the National Grid, as the scarcity increased in the second semester of the year.

Romania has already developed approximately 55 per cent from the economically available hydropower potential, mostly in large hydropower plant cascades. From the total installed capacity in hydropower plants of 6,389 MW, almost 653.9 MW of SHP are under the Grid Connection Contract and will be available after commissioning. From this capacity approximately 358.8 MW are in operation while the net capacity recorded by the National Dispatch Centre is close to 341.23 MW.

The biggest hydropower potential is concentrated in the mountain areas, and especially within Carpathian Mountains Arch in Transilvania region. The most important hydrographic basins which are suitable for the small hydroelectric power plant development belong to the Mures, Arges, Buzau, Jiu, Crisurile, Nera, and Siret rivers. In 2017, there was an increase of 2.3 per cent for the gross consumption in the National Grid to a value of 60,852 GWh compared to a consumption of 59,455 GWh in 2016. The gross production of energy was 63,748 GWh in 2017, a decrease from 64,472 MWh in 2016.

In 2013, the Romanian Government issued GD 57/2013, which established the modifications to the Renewable Energy Promotion scheme defined by the Law 220/2008. Because of the legal modifications which affected the number of green certificates and the limitation in annual quota, a large number of green certificates are no longer being traded and the renewable energy producers are not able to transform this form of incentives into cash-flow. The producers kept their untraded green certificates, which led to a drop in price to the minimum value granted by the current legislation, which is 30 EUR (US$ 34) instead of the higher value of 55 EUR (US$ 63). Consequently it has been difficult to attract financial support for green energy projects. However, introduction of the feed-in-tariff was announced and approved by the Government and EU Commission as a new promotion scheme for the renewable energy sources. The National Energy Regulator Agency and Energy Ministry were in charge of the establishment of the feed-in-tariff values per each technology and source. Although the feed-in-tariff was expected to clear some doubts and assure for the investors a foreseeable cash-flow and predictable environment only for the capacity up to 500 kW, unfortunately the implementation was delayed as well. Now a new plan for the promotion of renewable energy sector for 2020 – 2030, intended to increase the quota (27 per cent by the end of 2030) of the renewable energy in the annual consumption, is in the development phase within the EU framework (EU proposal COM (2016) 767 2016/0382), but so far, no guidelines or intentions were presented by Romania decision makers.

Renewable energy policy

The promotion scheme for renewable energy project development was established by Law 220 from 2008. At the beginning the promotion scheme was according to one Green Certificate (GC) for each MWh from all renewable energy sources including hydro (up to 10 MW), wind, solar, biomass, biogas and geothermal, for a 15 years period. In 2010, the promotion scheme was changed, making Romania one of the most attractive countries for the renewable energy sources, granting different numbers for green certificates for each renewable energy source as follows: 3 GC for small hydropower and 2 GC for refurbished ones for 10-year period, 2 GC for wind for the first 5 years and then 1 GC for the following 10 years, 6 GC for the photovoltaic projects and 4 GC for biomass and biogas.

In 2013 Law 220/2008 was modified with GD 994/2013 and a number of Green Certificate (GC) were delayed until 2017 and 2018 (wind only). This decision was taken in order to reduce the impact to the end-user bill by the incentives granted to the renewable energy. But the promotion scheme established by Law 220/2008 has ended in 2016 and therefore, only the renewable energy projects that were commissioned by the end of 2016 were granted with the green certificates scheme. In 2018, there were no promotion schemes for renewable energy projects. Consequently no other significant projects were developed or built in 2017.

Barriers to small hydropower development

Romania is rich with the renewable energy resources especially wind (grid connection request for 20 GW), photovoltaic and hydropower, but only a small fraction of this potential is used.

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

- No current legislation for promotion of the renewable energy with green certificates of other financial aids, making the investment not so attractive for investors.
- A very complex procedure in order to obtain the Water Management Approval and securing a location for the SHP plant development. In order to obtain the water use approval, the investor has first to rent the necessary surface of the minor river bed after a public tender and then apply for the water permit.
- The water cost for power generation was increased in 2010 five times from 0.24 RON (0.060 US$) to 1.1 RON (0.27 US$) per 1,000 m^3. This affects the cash-flow and the feasibility of the projects especially for the low-head small hydroelectric power plants. For example, for a 5 metres head project, the water costs will reach up to 76 per cent of the energy income (without green certificates incentives).
- Because of the increase in the development of SHP in the last few years in the upper sector of the mountain areas, a large number of environmental activists have emerged asking for the termination of works and stopping this kind of investment. One of the biggest campaigns was done by the World Wide Fund for Nature, a powerful Environmental protection NGO that has a programme of protecting the hydrographic basin of the Danube River and therefore protecting every tributary and affluent within this catchment area basin.

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4.1.8

Russian Federation

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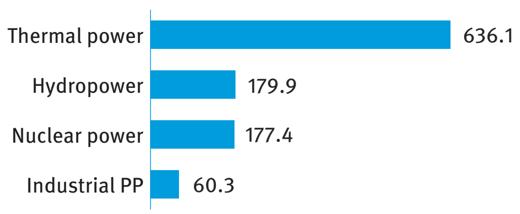
Key facts

Population	146,804,372[1]
Area	17,125,191,000 km^2 [2]
Climate	The climate of the Russian Federation varies considerably. The country has a humid continental climate in much of its European Plain in the western part of the Russian Federation, subarctic in Siberia region to the centre-north, and a tundra climate 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 –25 °C, varying from 0°C in the North Caucasus to –50 °C in the Republic of Yakutia. The average temperature in July is 15 °C, but it can be as low as 1 °C in the northern coastal areas of Siberia and reaching 25 °C in the Caspian region.[3,4]
Topography	Broad plain with low hills west of the Urals, vast coniferous forest and tundra in Siberia, and uplands and mountains along the southern border regions. The lowest point is the Caspian Sea (28 metres below sea level) and the highest point is Elbrus Mountain (5,633 metres, the highest point in Europe).[3]
Rain pattern	The Russian Federation 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 571 mm. It is highest in July (61.6 mm) and lowest in February (16.7 mm). Most precipitation falls in the north-west, with amounts decreasing from the north-west to south-east across European Russia.[4,5,6]
Hydrology	The Russian Federation possesses about 20 per cent of the global freshwater resources, but this water is rather unevenly distributed within the territory. About 90 per cent of the discharge of the Russian rivers belongs to the Arctic basin. Thus, the central and southern regions of European Russia, where 80 per cent of the population and industry is concentrated, have only 10 per cent of the freshwater resources.[7]

Electricity sector overview

The Russian Federation is one of the top producers and consumers of electric power in the world.[8] 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 such as Russian Far East, Siberia, Russian North, and Caspian.[9] Russia has rich gas, oil, and coal reserves, thus electricity is mostly generated by thermal power plants (including those fuelled by oil, gas and coal, geothermal and solar power plants), but nuclear and hydropower are also providing a significant contribution (Figure 1).

Figure 1.
Annual electricity generation by source in the Russian Federation (TWh)



Source: UES System Operator [10]

The UES Group of Russia provides most of the country's electricity and exports power to neighbouring countries over the network of the United Energy System of the Russian Federation (UES). UES is the largest centrally controlled electric power system in the world stretching from east to west about 7,000 km and from north to south for over 3,000 km. It comprises 748 power stations over 5 MW each.[10]

As of 1 January 2018, the total installed capacity of UES power plants was 239,812.2 MW. The power distribution is performed over more than 2.5 million km of electric transmission lines controlled by seven major regional Joint Energy Systems spread across 81 Russian Federation constituent entities.[10]

The total net electricity generation in 2017 was 1,054 TWh while the total electricity consumption was 1,040 TWh.[10]The UES of Russia is working in parallel with the UES of Kazakhstan, Ukraine, Belarus, Estonia, Latvia, Lithuania, Georgia, Azerbaijan, etc. based on the bilateral agreements (for example, the Agreement on Parallel Work of Electric Energy Systems of the Republic of Kazakhstan and the Russian Federation signed on 23 April 2010).[11,12] The Russian Federation is working together with other members of the

Eurasian Economic Union towards establishment of a joint energy market and transition to a coordinated energy policy. Hydropower plants are one of the key UES components providing 20.3 per cent of the total installed capacity and over 90 per cent of the regulated power capacity reserve. The total installed capacity of the UES grid-connected hydropower plants in Russia is about 48,085.9 MW (January 1, 2017).[13] The Federal hydropower generation company, OAO RusHydro, owns the main part of the hydropower plants in Russia. As of January 1, 2017, the Government of the Russian Federation owned approximately 60.6 per cent of RusHydro's share capital.[14]

The Federal Grid Company of UES is the owner and operator of the Unified National Electricity Grid (UNEG). The two principal types of activity conducted by the Federal Grid Company of UES are:

- Transmission of electrical power over the electrical grids, and
- Provision of technological connections for electricity consumers, the power plants of generating companies and the transmission facilities of other owners to the electrical grid.

These activities are both natural monopolies and therefore regulated by the State. The Company's assets include more than 140,000 km of transmission lines and 939 substations. The largest shareholder of UNEG, with an 80.1 per cent stake, is PAO Rosseti owned by the Russian Federation Government.[15] The electrification rate is 100 per cent.[16,17] Russian Federation was ranked 10th in the world by the availability of electrification by the World Bank in 2018 as well as scored 8 out of 8 in regards to the power supply reliability and transparency of the tariffs.[18]

However, several structural problems in 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.[19] These regions rely on the local power generation facilities and imported fuel for the power plants.[20] Yakutia is a typical example of such a region where a local company OAO SakhaEnergo is supplying electric power to the area (about 2.4 million km^2 occupied by population of 105,000, i.e. about two-thirds of the total population of Yakutia) mostly by means of the 136 autonomous diesel plants.[21]

There are occasional problems with access to the power supply in the areas located in the European part of Russia, e.g. Kaliningrad oblast.[22,23] These problems arise either due to an insufficient local power infrastructure or external influences since these regions are still interconnected to the former parts of the Soviet power grid which are currently located abroad.

Electricity will be playing an increasing role in the future Russian energy mix. Russian electricity consumption is expected to increase by nearly 2 per cent annually.[24] The main strategic objectives for the Russian electricity industry are modernization of the existing generation capacities and implementation of new generating technologies, including an accelerated development of renewable energy capacities. The Federal Law on the Electric Power Energy No. 196-FZ dated 26 March 2003 was updated in 2016 by inclusion of the enhanced requirements for the reliability and safety of the electric power facilities and distribution systems.

The electricity prices in Russia have been gradually liberalized and the majority of wholesale electric power is traded at non-regulated market prices. The reform assumes transition to a fully non-regulated electric power market in the future.

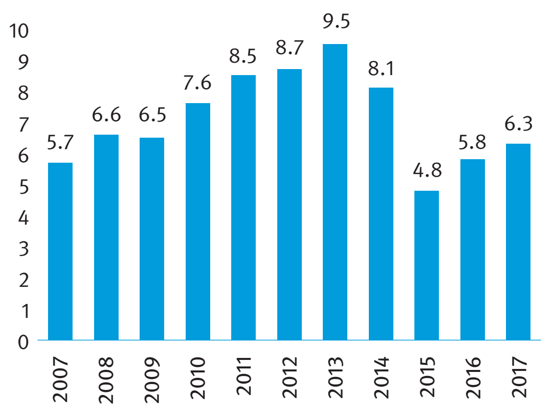
The Russian electricity generation market consists of a wholesale and retail markets. However, the liberalization of the Russian electricity market currently applies only to the wholesale sector. The public tariffs are likely to remain State-regulated for the foreseeable future. For the purpose of electricity price control, the whole country is split into pricing zones (1. European Russia-Ural, and 2. Siberia), and non-pricing zones (Kaliningrad oblast, Far East, Arkhangelsk Oblast and the Komi Republic) (Figure 2).

Figure 2.
Energy market pricing zones in the Russian Federation

Source: Recent Regulatory and Market Developments for RES-E in Russia[25]

Note: Areas not numbered are the non-pricing electricity market zones.

Figure 3.
Average electricity tariff (US$) per 100 kWh for residential consumers in the Russian Federation in 2007-2017



Source: Russian Federation Federal State Statistics Service[27]

Note: The actual tariffs in 2015 were increased, but their US$ value reduced. due to the liberalization of the rouble/dollar exchange rate.

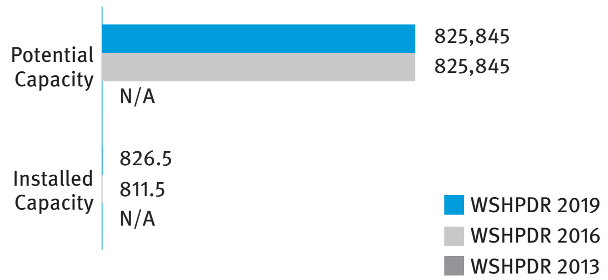
The reason for such division is a limited capacity of interconnection between these zones within UNEG and different structures of the production capacity, e.g., predominance of relatively cheap hydropower in Siberia.[26] The State regulates electricity prices in the non-pricing zones because electricity supply is totally isolated from UES in those areas. The electricity tariff for the end consumer in the retail market steadily increased over the past years.[27]

The responsibility for setting regulated tariffs for electricity and capacity supplied for the residential consumers as well as tariffs for the electricity supply in the non-pricing zones lies with the Federal Anti-Monopoly Service (FAS).[28] FAS is also regulating the tariffs for the renewable energy, e.g. in case of electric power purchased in order to compensate for the grid losses.[29]

Small hydropower sector overview

The current regulatory small hydropower (SHP) definition in Russia is described as the hydropower plants with an installed capacity up to 30 MW and a turbine wheel up to 3 metres.[30] The installed capacity of SHPs up to 10 MW is 169.6 MW, and up to 30 MW is 826.5 MW, while the technically feasible potential for SHP <30 MW is estimated to be 825,844.6 MW, indicating that only about 0.1 per cent has been developed (Figure 4, and Table 1). The installed capacity has changed between the *World Small Hydropower Development Report* (*WSHPDR*) *2016* and *WSHPDR 2019* (Figure 5) due to both a more accurate historic data becoming available and commissioning of new SHP plants.[31]

Figure 4.
Small hydropower capacities 2013/2016/2019 in the Russian Federation (MW)



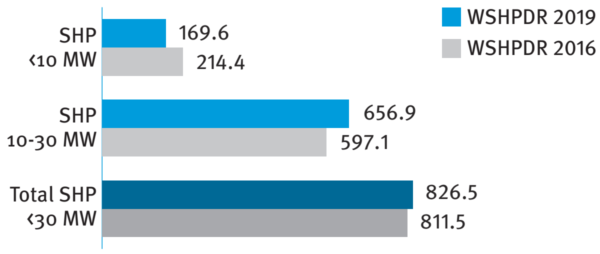
Source: *WSHPDR 2013*,[63] *WSHPDR 2016*[31]

Note: SHP up to 30 MW.

Note: The comparison is between data from *WSHPDR 2013, WSHPDR 2016* and *WSHPDR 2019.*

SHPs are usually developed on small rivers. The small rivers are defined in the Russian Federation as a river less than 100 km long with the watershed area less than 2,000 square kilometres located within a single geographical zone.[32] Small rivers are prevalent in the hydrographical network of the Russian Federation. The share of small rivers shorter than 100 km in the total length of the hydrographical network is 95 per cent, while their total flow constitutes about 50 per cent of the total flow of the Russian rivers.[33] The potential technically feasible capacity of the small rivers in Russia for producing hydropower is estimated at approximately 372 GWh per year.[34]

Figure 5.
Small hydropower installed capacities 2016-2019 in the Russian Federation (MW)



Source: Various [31,33,43,44,45,46,47]

SHP plants in the Russian Federation were initially defined in the Soviet period by the regulation SNiP 2.06.01-86, which classified plants with the total installed capacity up to 30 MW and a turbine wheel up to 3 metres as SHP.[35] This definition was also included in the Russian Federation Standard 51238-98 (1999) which defined the SHP terminology, but omitted later in the regulation SP 58.13330.2012 introduced in 2013.36,37 Therefore, no official SHP definition for Russia was quoted in the *WSHPDR 2016*.[31] The revised SP 58.13330.2012 published in 2017 reinstated the old definition of SHP plants established in SNiP 2.06.01-86.[38]

The state regulation and strategic planning of the Russian energy industry are primarily concerned with power plants over 25 MW.[39,40] There are special State support measures for the electric power plants with installed capacity less than 25 MW that are officially qualified as renewable energy sources.41 Consequently, the 25 MW threshold is assumed in many publications regarding SHP in the Russian Federation.

The current report is considering SHP plants with an installed capacity up to 10 MW, but information about Russian SHP plants with an installed capacity <25-30 MW is also referenced. The numbers of SHP plants operating in the Russian Federation published in Russian sources vary from 60-70 to 200-300, with the higher values found in the earlier reports.42,43 In order to clarify this discrepancy, an array of information about SHP plants in the Russian Federation was summarized in the *WSHPDR 2016* concluding that actual number of operating SHP plants with installed capacity below 10 MW was just over a hundred.[31]

The overview of SHP plants is updated using the data utilised in the *WSHPDR 2016* and various recent publications (Table 1). The majority of the currently operating SHP plants are located in the North Caucasian region and the Republic of Karelia. The number of operating SHP plants of installed capacity <30 MW each increased from 134 (*WSHPDR 2016*) to 139. However, only two new SHP plants were actually constructed in the period between the *WSHPDR 2016* and *WSHPDR 2019* while other SHP plants were identified from the historic data.

Table 1.
Overview of SHP plants operating in the Russian Federation

	Federal District	*Estimated potential capacity, MW (SHP <30 MW)*			*SHP <10 MW*			*SHP 10-30 MW*			*Total SHP <30 MW*		
		Theoretically available	*Technically feasible*	*Economically feasible*	*Number of SHP plants*	*Total installed capacity, MW*	*% Technically feasible capacity*	*Number of SHP plants*	*Total installed capacity, MW*	*% Technically feasible capacity*	*Number of SHP plants*	*Total installed capacity, MW*	*% Technically feasible capacity*
1	North-Western	121,222.2	33,377.8	19,755.6	21	27.3	0.1	9	219.5	0.7	30	246.8	0.7
2	Central	18,688.9	6,466.7	3,488.9	23	43.1	0.7	2	58.8	0.9	25	101.9	1.6
3	Southern	100,444.4	30,666.7	17,111.1	5	11.6	0.0	1	28.9	0.1	6	40.5	0.1
4	North Caucasian	35,111.1	10,666.7	5,555.6	25	52.2	0.5	11	215.3	2.0	36	267.5	2.5
5	Volga	300,000.0	93,555.6	51,400.0	21	9.6	0.0	4	91.3	0.1	25	100.8	0.1
6	Ural	77,777.8	25,333.3	14,000.0	6	12.1	0.0	0	0.0	0.0	6	12.1	0.0
7	Siberian	966,800.0	301,777.8	166,222.2	7	8.3	0.0	0	0.0	0.0	7	8.3	0.0
8	Far Eastern	1,003,777.8	324,000.0	178,000.0	4	5.4	0.0	2	43.2	0.0	6	48.6	0.0
Total		**2,623,822**	**825,844.6**	**455,533.4**	**112**	**169.6**	**0.0**	**29**	**656.9**	**0.1**	**141**	**826.5**	**0.1**

Source: Various [31,33,43,44,45,46,47]

SHP plants have a long history in the country. The first hydropower plant (0.18 MW) was constructed in the Altai region in 1882 for powering the water pumps at the Zyryanovsky mine. There is a unique example, an SHP plant named 'Porogy' (1.45 MW) constructed in the Chelyabinsk region in 1910, which is still operating.[48] 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 when over 6,500 SHP plants were operating in the Russian Federation.[49] The State energy policy was changed later in favour of the major hydropower plants. Therefore, the production of SHP equipment was halted and the majority of SHP plants were taken out of the operation, and consequently become derelict. Surveys have been carried out proving that restoration of some of these SHP plants can be economically feasible.[50]

The SHP energy sector is experiencing a revival in the Russian Federation. The country possesses a variety of SHP technologies and produces equipment for SHP plants.[51] There are several SHP development plans. RusHydro and NordHydro are the major developers of SHP plants in the Russian Federation. RusHydro's development programme includes the construction of SHP plants with a total installed capacity of 850 MW.[52] NordHydro is currently preparing designs for the reconstruction of 36 SHP plants and construction of 10 new SHP plants in the company property, and their strategic plan for the period up to 2025 includes the construction of SHP plants in 21 regions of the Russian Federation.[53] There are twelve SHP plants currently under construction across the country with a total installed capacity about 170 MW, and opportunities for the new SHP projects are explored.

The Resolution of the Government of the Russian Federation No. 861-r from 28 May 2013 established the targets for development of SHP installed capacity in 2014-2020.54 However, these SHP development targets have not been met so far. They were revised in 2017 towards a noticeable reduction of the total planned SHP installed capacity, while their implementation was extended up to 2024.[55]

The 'Programme of Development of the United Energy System for 2017-2023' approved by the Ministry of Energy of the Russian Federation includes construction of five SHPs, two in the Republic of Karelia (24.9 MW each) by NordHydro and three by RusHydro in the North Caucasian Federal District (16.8 MW in total).[56]

There are manifold possibilities to gain financial support for SHP projects. The responsibility for developing SHP in the Russian Federation lies with the regional (municipal) authorities and private investors. Regional authorities interested in the development of SHP are capable of financing studies of the hydropower potential in the region, but further implementation usually depends on private investors. For example, one of the main investors in the SHP projects in Russia, NordHydro, has concluded agreements for cooperation in development of SHP plants with the regional authorities in five Federal Districts of the Russian Federation – North-Eastern, Central, Volga, Ural, and Siberian.[53]

The use of renewable energy sources (including SHP) is considered in the Russian Federation as part of the broader concept of energy efficiency.[57] The main guarantee to the renewable energy investors is provided under the Federal Energy Efficiency Law regarding the determination of the special tariffs for energy efficiency investments including renewable energy projects.[58] Those entities that have invested in the 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 Russian Federation Law on Electric Power Energy provides a number of mechanisms for supporting the development of renewable energy in Russia.[59] Special State auctions are held each year selecting renewable energy investment projects (wind, solar, and SHP). Agreements for the Delivery of Capacity are concluded between the renewable energy investors and wholesale market consumers. By signing these Agreements, investors commit to construct a certain type of production installation of a certain capacity, and at a certain location. They also guarantee availability of their installations for electricity production. In return, investors are remunerated at regulated tariffs.

SHP plants with an installed capacity of <25 MW that participate in the retail electric power market can 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 renewable energy sources;
- Establishment of feed-in tariffs (FITs) for renewable energy that account for a certain return on the investment (currently at 14 per cent);
- Obligation of the grid companies to buy renewable energy despite the difference in tariffs (i.e., renewable energy tariffs are now 3.5 times higher than those for conventional energy generators).[60]

Apart from utilizing the investment support mechanisms available in the Russian Federation, investors can benefit from the international incentives. For example, the mechanism of "joint projects with third countries" allow EU Member States to support the construction of renewable energy installations in non-EU countries.[61] This support mechanism is relevant for the renewable energy projects in the north-west of the Russian Federation since they are capable of exporting the electric power to the EU over the existing links with adjacent countries (Finland, Estonia, and Latvia).

Renewable energy policy

The renewable energy policy in the Russian Federation is defined in the Order of the Government of the Russian Federation No. 354-R from February 28, 2017 'About approval of the main directions of the State policy in regards to the energy efficiency in the electric power industry for the period up to 2024'.[55] This policy consider accelerated development of the renewable energy sources as an important factor of the economic modernization of the country. The main areas of the renewables development in the Russian Federation are wind and solar energy projects, with SHP playing a comparatively minor role.

The share of renewable energy in the total electric power generation within the United Energy System is expected to increase from about 0.1 per cent in 2016 up to 0.39 per cent by 2020.[57] The targets are established for the State, but not for the electric power generating companies. These targets are not legally binding, and there would be no fines for failing them (as it has happened already).

The Energy Strategy of the Russian Federation provides requirements for the advanced development of SHP technologies as well as improvements in the industrial facilities producing equipment for SHP plants. The country will develop the renewable energy sector, taking into account the structure and features of the national energy industry.

An intensive utilization of renewable energy sources in the Russian Federation would bring a number of important benefits such as:
- Electric power supply for the isolated consumers, i.e. those who do not have access to the centralized electric power distribution grids;
- Reduction of the liquid fuel supplies to the remote northern areas of Russia including the Arctic region (e.g. replacing local diesel generation with renewable energy sources);
- Increased reliability of the electric power supply in areas with the centralized electric power distribution grids, particularly those experiencing shortages of the electric power supply;
- Reduction of the air pollution resulting from the thermal power stations fuelled by coal or oil.

The Russian Federation joined the International Agency for Renewable Energy (IRENA) on 22 July 2015.[62] This membership allows the Russian Federation to participate in the development of the international renewable energy standards, and adopt the best practices and advanced technologies.

Barriers to small hydropower development

The main barrier for developing the renewable energy projects, including SHP, in the Russia Federation is the availability of vast fossil fuel resources, as well as the importance of the Russian gas, oil, coal, and nuclear industries to the economy of the country. Other significant barriers to developing SHP projects in the Russian Federation are:

- A lack of the state-supported programmes for SHP development;
- Lengthy procedures for land allocation and State approvals for the projects, that can sometime last for many years;
- Excessive requirements for the projects imposed by the regional grid companies for provision of the grid connection;
- A shortage of up-to-date scientifically proven data on the regional capacity for developing SHP projects;
- A lack of standard technical and methodological regulations, information technologies and software required for designing, constructing and operating renewable energy generation plants;
- A lack of training for specialists and skilled professionals at the regional level;
- Insufficient state support in the development of the SHP technologies;
- Natural and environmental constraints, e.g. seasonal restrictions (frost, floods), locations in environmentally sensitive areas, etc.

The Federal budget does not provide finance for SHP projects. Russian banks are reluctant to finance SHP projects due to the long-term period of recoupment for such investments. Consequently, there are many examples in the Russian Federation of the construction of SHP plants being put on hold.

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4.1.9 Slovakia

Frantisek Janicek, National Centre for Research and Application of Renewable Energy Sources

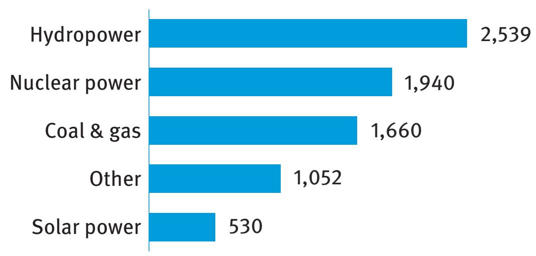
Key facts

Population	5,442,974[1]
Area	49,035 km^2 [2]
Climate	Slovakia has a moderate continental climate, with four distinct seasons. Summers tend to be hot, while winters are cold, cloudy and humid. The average daily temperature ranges from –3 to 2 °C in January, and 16-26 °C in July. Temperatures are lower in the mountains.[3]
Topography	The topography of Slovakia features mountains in the central and northern part of the country, and lowlands in the south. The highest peak is Gerlachovsky Stit (2,655 metres) in High Tatras mountains along the Polish border, and the lowest point is the Bodrog River (94 metres) in the south-east. The capital city Bratislava is situated in Slovakia's largest region of plains, where the Danube River forms a part of the border with Hungary.[4]
Rain pattern	Annual precipitation in the form of rain and snow ranges from 500 mm in the south-west of Slovakia to about 20,000 mm in the mountains. In winter, most of the precipitation is in the form of snow, while summer is characterized by frequent storms with strong rainfalls.[3]
Hydrology	Most of the Slovakia's rivers flow south into the Danube, which, together with the Morava, forms the country's south-western border. From a point a few kilometres south of the Slovakian capital of Bratislava, the main channel of the Danube River demarcates the border between Slovakia and Hungary for about 175 kilometres. As it leaves Bratislava, the Danube separates into two channels. The main channel, the Danube proper, continues southward along the border with Hungary. The smaller channel, called the Little Danube, branches eastward and then southeast to meet the Váh River. The Váh continues south and converges with the Nitra and with the main branch of the Danube at Komárno. The Hron and Ipel' Rivers also flow south and enter the Danube before the latter turns south into Hungary. Slovakia's eastern rivers also tend to flow to the south, eventually entering the Danube. Among them are the Hornád and the Ondava. The Poprad, also in the east, is the only sizable river that flows northward, into Poland.[13]

Electricity sector overview

The total installed capacity was 7,721 MW in 2017. However, due to a long-term shutdown of several conventional thermal power plants, the available capacity was approximately 3,500 MW. Approximately 30 per cent of the capacity came from the fossil fuel power plants, 33 per cent from the hydropower, 25 per cent from the nuclear, 7 per cent from the photovoltaic and 5 per cent from other sources (see Figure 1).[5]

Figure 1.
Installed electricity capacity by source in Slovakia (MW)



Source: National Grid Control Centre of Slovakia[5]

Figure 2.
Location of power plants in Slovakia

Source: Janíček et al.[7]

Legend: blue – hydropower, light blue – nuclear power, red – thermal power.

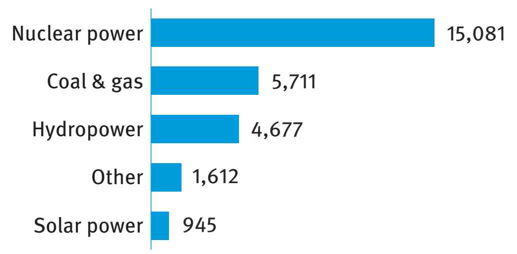
The power production plants are concentrated in the west part of the country, where both Mochovce and Jaslovské Bohunice nuclear plants are located, as well as the Gabcikovo, a large hydropower plant with 720 MW installed capacity.

The next most important region is Povazie on the river Vah, where there are many hydropower plants collectively named Vagus's Cascade and a pumping power plant in Cierny Vah with a capacity of 735 MW. The conventional thermal power plants are located in Novaky, near lignite mines, and in Vojany, where hard coal is imported from the east. Distribution of the power plants can be seen in Figure 2.[7]

In 2017, the total net electricity generation was 28.03 TWh and consumption was 31.06 TWh. Approximately 54 per cent of the net generation came from the nuclear power, 17 per cent from the hydropower, 20 per cent from coal or gas, 3 per cent from solar and 6 per cent from other sources (see Figure 3).[5] Slovakia has 100 per cent electrification rate. Slovakia is close to balanced consumption and production of electricity, but consumption has been increasing in recent years. In 2017 Slovakia was a minor importer of electricity due to the fact that it was more economical to import electricity than to produce it, and due to preceding years of lower-than-expected rainfall.[6]

While the gross domestic product (GDP) is growing (3.4 per cent in 2017), the consumption of electrical energy is stagnating.[1] Between 2007 and 2017, total primary energy consumption decreased by 7 per cent. This is due to a greater efficiency of electrical products, the use of modern production technologies and the economisation caused by the deregulation of energy prices.[6] The Ministry of Economy is expecting slow growth in electricity consumption and the country is finishing two new blocks of the Mochovce nuclear plant. Once operational, Slovakia is expected to be a net exporter of electricity.[5]

Figure 3.
Annual electricity generation by source in Slovakia (MWh)



Source: National Grid Control Centre of Slovakia[5]

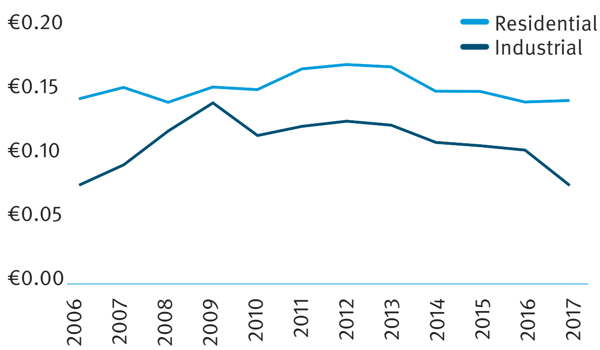
The entire electricity transmission network is owned by the state-owned company Slovenská elektrizačná prenosová sústava, a.s. (SEPS). There are also three regional Distribution System Operators (DSO) that are 51 per cent state-owned – Západoslovenská energetika, a.s. (Western Slovak Power Utility), Stredoslovenská energetika, a.s. (Central Slovak Power Utility) and Východoslovenská energetika, a.s. (Eastern Slovak Power Utility).[11]

Generation and wholesale activities were liberalized in January 2005. The main player in the Slovak electricity generation market is Slovenské elektrárne (SE), a joint stock company of which 66 per cent is owned by Enel, the Italian based multinational group, with the other 34 per cent owned by the state.[13] SE is the biggest electricity provider in Slovakia with 82 per cent of the country's generation market.[1]

The Slovak Republic is a member of the European Union (EU) and is obliged to adhere to EU policies. One of the main objectives is the gradual transition to a low carbon economy. By 2020, Slovakia has an obligation to generate 14 per cent of electricity from the renewable energy sources. By 2030 this rises to 20 per cent. The Slovak power system is fully integrated into the European Network of Transmission System Operators (ENTSO-E).

As of 2017 the average electricity price for medium-sized households, including all taxes and levies, was 0.1435 EUR (US$ 0.17) per kWh which was well below the EU average. The average cost for medium-sized industrial consumers, not including taxes, during the same period was 0.0771 EUR (US$ 0.09) per kWh which was slightly higher than the average rate across the EU (see Figure 4).[11]

Figure 4.
Electricity cost to consumers in Slovakia, 2007 - 2017 (EUR/kWh)



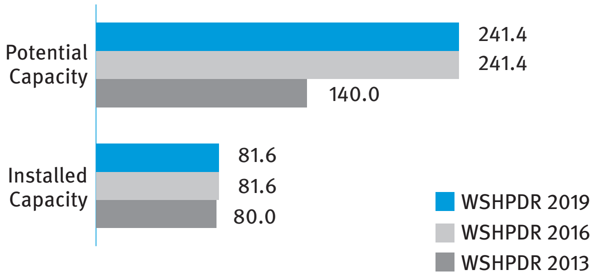
Source: Eurostat[10]

Small hydropower sector overview

Slovakia defines small hydropower plants as plants with less than 10 MW installed capacity. Total small hydropower installed capacity is 81.6 MW with an estimated potential of at least 241.4 MW indicating that approximately one-third of the total potential has been developed. Compared to the data from the 2016 *World Small Hydropower Development Report* both the installed capacity and estimated additional potential capacity have not changed (see Figure 5).

There are currently 217 small hydropower plants in operation generating 281.8 GWh (Table 1). This contributes 3 per cent of the total electricity generated from hydropower and less than 1 per cent of the country's total generation.[9]

Figure 5.
Small hydropower capacities 2013/2016/2019 in Slovakia (MW)



Source: Atlas of Renewable Energy Sources,[9] *WSHPDR 2013*,[14] *WSHPDR 2016*[15]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

Table 1.
Small hydropower in Slovakia

Power Rating	*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: Atlas of Renewable Energy Sources[9]

Table 2.
Proposed small hydropower plants

River Basin	*Number*	*Installed capacity [MW]*	*Generation (GWh)*
Dunaj	19	10.28	69.29
Vagus	121	64.91	316.86
Hron	129	57.17	272.73
Bodrog & Hornad	99	27.51	138.38
Total	**368**	**159.87**	**797.25**

Source: Atlas of Renewable Energy Sources[9]

The potential of large rivers for large hydropower plants in Slovakia is almost completely developed. However, small hydropower potential still exists.[8] Based on the gradual transition to a carbon-free economy and on the "Plan for Hydroenergy Power Utilization in Slovakia" up to 2030 there are plans to build up to 368 small hydropower plants (see Table 2). The total installed capacity of these plants is 160 MW with an annual production of approximately 797 GWh or 3 per cent of the total electricity consumption.[10] The total technical potential of Slovakia's rivers is 392,344 MW, with an annual production of 1,713.76 GWh of electricity. Many rivers, however, are located in protected areas preventing the construction. Many of the new projects are planned for construction on the Orava river, where a stretch of 24.6 km has a planned production of 107.5 GWh, however there are efforts to declare this stretch of the river a protected area. The Hron river is considered to be the most promising river for the construction of. There are 24 planned hydropower plants, of which three already own permits.[9]

Renewable energy policy

The objectives of the Slovak Energy Policy are to ensure an affordable, environmentally sensitive and reliable supply of electricity for all consumers. In line with the EU energy policy there is a support system for renewable energy systems in order to achieve a target 24 per cent share of the total electricity generated and 14 per cent share of the total energy consumption (including heat and transport) from the renewable energy sources by 2020. Renewable energy sources have priority connection to the electricity system, are eligible for feed-in tariffs, and can get investment support during construction. According to the RES Act from 2018, new sources have no guaranteed feed-in tariffs, but have to compete in the auction for the lowest price of the generated electricity. Part of the new act should ease the permission procedure on small hydropower sources, but the national council did not approve it because of the concerns on environmental impacts of SHP on the rivers.

Barriers to small hydropower development

There is little activity amongst investors because of the fears of a long return of investment, and of the complex process of obtaining permits. Government bodies have no active role in the development of small hydropower plants, because the country has stable power generation base with no need for further development of the power plants. There are several key challenges for small hydropower development:

- Administrative and environmental barriers are discouraging private investors. Other renewable energy sources, such as biomass, biogas and photovoltaic, have a shorter payback period than small hydropower plants.
- Construction of hydropower plants in Slovakia is also difficult due to the 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.
- Investors are required to obtain a permission according to the Slovak Water Act and an approval from various environmental organisations. Some of them are: environmental requirements, terms and requirements of the national water management authority, hydrological data, topographic references, geological references, local references data, and other references documentation. On the basis of these laws it is necessary to submit a number of documents addressing all the organizations, which is very challenging. Projects in these structures may be developed only by the authorized civil engineers.[8]
- There is a mistrust towards the construction of small hydropower plants from the general public and environmental activists.

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4.1.10 Ukraine

Petro Vas'ko and Maria Ibragimova, Institute for Renewable Energy

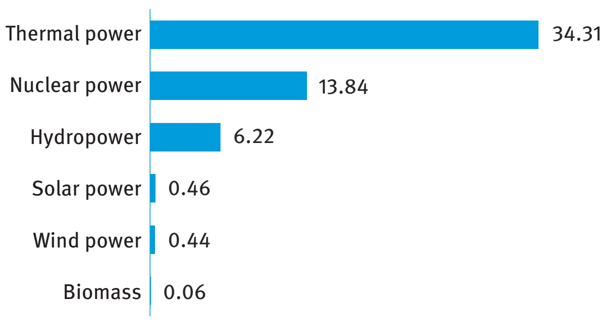
Key facts

Population	45,004,645[1]
Area	603,550 km^2 [1]
Climate	Temperate continental climate with a Mediterranean climate on the southern coast. The winter months, from November to March, are warmer along the Black Sea but colder further inland. The summer months from May to September are warm across the greater part of the country but hotter in the south. The average temperature in January is between -8°C in the north-east and the Carpathian highlands and 4 °C in the southernmost parts of the country. In July temperatures are 17 °C in the north-west, 19 °C in the Carpathians and 23 °C in the south.[1]
Topography	The greatest part of the country consists of fertile plains (steppes) and plateaus. Mountains are found only in the west (the Carpathians) and in the Crimean Peninsula in the extreme south. Mount Hoverla, which is part of the Carpathians, is the highest point in Ukraine at 2,061 metres.[1]
Rain pattern	Rainfall is disproportionately distributed across the country. The average annual rainfall ranges between 600 and 650 mm in the west and north-west to 300 mm in the south and south-east. Maximum rainfall occurs in the Crimean Mountains (1,000 – 1,200 mm) and the Carpathians (1,500 mm).[2]
Hydrology	There are 63,119 rivers and streams in Ukraine, 93 per cent of which are less than 10 km in length. The longest river is the Dnieper, which is approximately 2,201 km in length and is the fourth longest river in Europe. Generally, rivers in Ukraine flow from north to south and drain into the Black Sea. The highest drainage density of the river network is approximately 1.1 km/km^2 in the mountainous regions in the west of the country.[2]

Electricity sector overview

By the end of 2016, the total installed capacity of power plants in Ukraine was 55.33 GW.[3] Approximately 62 per cent was derived from thermal power (including combined heat and power) plants, while approximately 25 per cent was from the nuclear power plants. The remainder was derived from renewable energy, with both large and small hydropower plants and pumped-storage hydropower providing 11.2 per cent and other renewable energy sources providing approximately 1.7 per cent (Figure 1).[3]

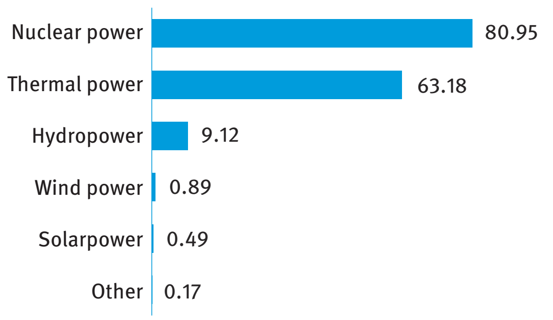
Figure 1.
Installed electricity capacity by source in Ukraine (GW)



Source: UKRENERGO[3]

Note: Including 3,942.7 MW from the uncontrolled territory of Donbass Power System (PS); excluding Crimea PS.

Figure 2.
Annual electricity generation by source in Ukraine (TWh)



Source: UKRENERGO[3]

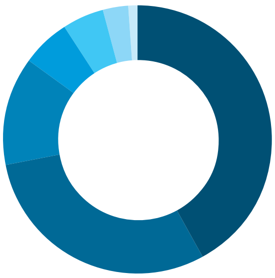
Note: Excluding Crimea PS and the temporarily uncontrolled territories of Luhansk and Donetsk regions.

The share of hydropower in the total installed capacity of Ukraine is approximately 11.3 per cent. Large-scale plants (over 10 MW) are located on the Dnieper (six hydropower plants with 3,835.34 MW of combined installed capacity), the Dniester (742.8 MW), the Tereblya (27 MW) and the Southern Bug (11.5 MW). Three pumped-storage hydropower plants have been commissioned at Kiev (235.5 MW), Dniester (972 MW) and the first stage units of Tashlyk (302 MW).[3] The total installed capacity of the pumped-storage hydropower plants is expected to achieve 4,074 MW by 2026.[4] Hydropower plants cover peak loads, control frequency and power, and provide mobile emergency reserve of power in the Integrated Power System of Ukraine. The total hydropower potential of Ukraine is over 44 TWh, while the cost-effective undeveloped potential is approximately 6.5 TWh.[5]

Total annual electricity generation in 2016 was 154.82 TWh. The main producers were nuclear (52 per cent) and thermal (41 per cent) power stations. Hydropower and other renewable energy sources accounted for only 6 per cent and 1 per cent of the total electricity generation, respectively (Figure 2).[3]

The electrification rate in Ukraine is 100 per cent.[7] The industrial sector is the biggest consumer of electricity, accounting for approximately 42 per cent of consumption, more than half of which is consumed by the metallurgy sector (Figure 3).[3]

Figure 3.
Electricity consumption in Ukraine (%)



Source: UKRENERGO[3]

The energy system of Ukraine ensures electricity exchange with the energy systems of other European countries (Hungary, Slovakia, Poland and Romania) as well as countries of the Commonwealth of Independent States (CIS) (the Russian Federation, Belarus, Moldova).[3] In 2016, there were no commercial electricity import supplies to the Ukrainian energy system. Ukraine exports electricity to countries of the European Union, namely Hungary, Slovakia and Romania, through the Burshtyn Island thermal power plant ("Island"). The "Island" functions in parallel with the European Network, ENTSO-E, and separately from the main part of the Ukrainian energy system. In 2016, the volume of the electricity exports from the Burshtyn Island thermal power plant to Hungary was 3,055.6 GWh and to Slovakia 0.1 GWh. The export supplies of electricity to Poland in 2016 were at the level of 957.4 GWh. There were no commercial electricity export/import supplies with CIS countries.[3]

The Integrated Power System (IPS) of Ukraine is central to the country's electric power industry. The IPS is a technical system consisting of power plants, substations, trunk/main power transmission and distribution lines. The State-owned Enterprise National Power Company Ukrenergo (SE NPC 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. The company's network includes eight regional power systems – Dniprovska (Dnipro), Donbaska (Donbass), Zakhidna (Western), Krymska (Crimean), Pivdenna (South), Pivdenno-Zakhidna (South-West), Pivnichna (North) and Tsentralna (Central) Power Systems. They are connected by high-voltage power lines of 220kV, 330kV, 400kV, 500kV and 750kV.[8]

Electricity generation is provided by:
- Energoatom, operating four nuclear plants, one 11 MW hydropower plant on the Southern Bug River and Tashlyk pumped-storage hydropower plant;
- Ukrhydroenergo, operating large and pumped-storage hydropower plants;
- Six private power generation companies (Dniproenergo, Zahidenergo, Shidenergo, Donbassenergo, Centrenergo and Kyivenergo), operating both thermal power plants and combined heat and power plants;
- Renewable energy and other small power producers.

According to the Law of Ukraine On Privatization, nuclear power stations, large hydropower plants, pumped-storage plants and main transmission power networks cannot be privatized. There are 24 private regional power distribution companies, which carry electricity to individual consumers by local electric networks.

Table 1.
Two-part tariff for SE PJSC Ukrhydroenergo in 2018

Quarter	*Hydropower plants (excl. pumped-storage power plants)*		*Pumped-storage power plants*	
	EUR	*US$*	*EUR*	*US$*
	payment for produced electricity			
1st quarter	0.003	0.003	0.037	0.044
2nd quarter	0.001	0.001	0.044	0.053
3rd quarter	0.004	0.005	0.055	0.066
4th quarter	0.001	0.001	0.043	0.051
	fees for operating capacity			
1st quarter	5.15	6.14	8.10	9.66
2nd quarter	2.60	3.10	14.19	16.93
3rd quarter	5.60	6.69	30.05	35.86
4th quarter	2.67	3.19	13.19	15.74

*excluding VAT

Source: NCSEPUR[11]

The National Commission for State Energy and Public Utilities Regulation (NCSEPUR) defined the cost of 1 kWh of electricity for 2018 as EUR 0.016 (US$ 0.019) for the nuclear power plants, and from EUR 0.053 (US$ 0.064) up to EUR 0.091 (US$ 0.108) for the thermal power plants (including combined heat and power plants).[9,10] Hydropower has a two-part tariff, which consists of payments for electricity and fees for the operating capacity. The hydropower tariff varies quarterly. For large-scale hydropower plants (above 10 MW and excluding pumped-storage plants) the rate of payment for electricity in 2018 ranged from EUR 0.001 (US$ 0.001) up to EUR 0.004 (US$ 0.005) per kWh, and the rate of payment for operating capacity ranged from EUR 2.6 (US$ 3.1) up to EUR 5.6 (US$ 6.7) per kW.[11] All costs are given without value-added tax (VAT). An example of detailed hydropower tariffs, fixed by NCSEPUR for the major operator of hydropower plants, Ukrhydroenergo, in 2018 is given in Table 1.

For producers of electricity from renewable energy sources (including hydropower plants of less than 10 MW) there are legally adopted Green Tariffs that will be valid up to 2030.[12] The tariff depends on the type of energy, capacity and the date the power plant was commissioned. For example, the tariff rate for small hydropower stations with capacities between 200 kW and 1,000 kW, which were commissioned in 2015, was set at EUR 0.14 (US$ 0.16) per kWh.[13]

In April 2017, the Parliament of Ukraine adopted the new Law of Ukraine On Electricity Market. Currently, the wholesale electricity market, based on a "single buyer" model, functions in Ukraine. The state-owned company Energorynok is the only buyer purchasing electricity from all producers and selling to all suppliers at a single wholesale market price. The wholesale market price is formed by the National Commission for State Regulation of Energy and Public Utilities. According to the Law, the current electricity market will be reorganized into a liberalized electricity market model on July 1, 2019 and will include bilateral contracts, a day-ahead market, an intraday market, a balancing market, a market for ancillary services and a retail market. The Law also envisages a new mechanism to stimulate "green" tariff electricity producers. In accordance with the Law, renewable power producers shall sell the electricity to the so-called Guaranteed Buyer (a state enterprise to be designated later by a separate resolution of the Government – most likely, State Enterprise Energorynok) under bilateral contracts at the Green Tariff. The Guaranteed Buyer then re-sells the electricity at the day-ahead and intraday markets. Until 1 July 2020 the compensation to the Guaranteed Buyer (the difference between the Green Tariff and the price of electricity sold at the day-ahead and intraday markets) shall be made by the operator of nuclear power plants; later and until 1 January 2030 – by the transmission system operator (currently Ukrenergo) as a payment for the Guaranteed Buyer's services for the increase in the share of electricity generated from alternative energy sources.[14,15]

Small hydropower sector overview

Ukraine defines small hydropower as hydropower plants with less than 10 MW of installed capacity (Table 2).[12]

As of the end of 2017, the total installed capacity of small hydropower in Ukraine stood at approximately 95 MW and was comprised of about 150 small hydropower plants, including 136 small hydropower plants operating under the Green Tariff.[6]

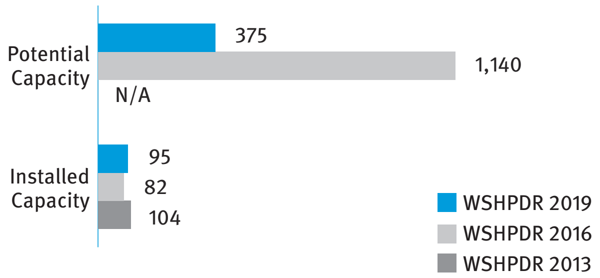
Table 2.
Small, mini and micro-hydropower classification in Ukraine

Type	*Classification*
Micro-hydropower	less than 200 kW
Mini-hydropower	200 kW - 1 MW
Small hydropower	1 MW - 10 MW

Source: Verkhovna Rada[12]

The total hydropower potential of small rivers of Ukraine is about 12.5 TWh/year. According to the Energy Strategy of Ukraine for the Period until 2030 (adopted in 2006), small hydropower potential capacity was estimated at 1,140 MW with an annual electricity production of 3.34 TWh/year.[5] However, the introduction of the Green Tariff in 2009 reduced the definition of small hydropower plants from less than 30 MW to less than 10 MW. Furthermore, there are several national laws and programmes as well as international agreements, conventions and additional protocols on protection, conservation and sustainable use of natural resources, which defined restrictions on the use of small river resources. Following the Government's request, the Institute for Renewable Energy performed research work on estimation of the potential resources of the small rivers of Ukraine in 2017. The technical potential of small rivers of Ukraine was set at 375 MW with an annual electricity generation of 1.27 TWh/year. This potential capacity includes 95 MW of developed potential, 10 MW of small hydropower plants which must be restored, and 270 MW of undeveloped potential.[20] Compared to the results of the *World Small Hydropower Development Report (WSHPDR) 2016*, installed capacity has increased by 16 per cent, whereas potential capacity, as a result of the recent re-evaluation, has decreased by 67 per cent (Figure 4).

Figure 4.
Small hydropower capacities 2013/2016/2019 in Ukraine



Source: SAEE,[6] Vasko et al.,[20] *WSHPDR 2013*,[32] *WSHPDR 2016*[33]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

The majority of the operating plants are situated in the Vinnitsa region where total capacity exceeds 20 MW, and the Kirovograd, Ternopil and Transcarpathian regions have the highest level of installed capacity.[6] The greatest potential is concentrated in the Zakarpattya, Lviv, Ivano-Frankivsk, Chernivtsi, Zhytomyr, Poltava regions.[20]

Renewable energy policy

Key targets for the renewable energy development are indicated by the National Action Plan for Renewable Energy for the period until 2020 (NAPRE).[16] The main goal of the NAPRE is to achieve an 11 per cent share of energy from the renewable sources in the final energy consumption in the country by 2020. Source-specific targets for 2020 are shown in Table 3.

Table 3.
National targets in renewable energy development by 2020

Category of electric power facility	*Installed capacity (MW)*	*Generation (GWh)*
Photoelectric power plants	2,300	2,420
Wind power plants	2,280	5,900
Hydroelectric power plants, including:	5,350	13,340
< 10 MW	150	340
> 10 MW	5,200	13,000
Bioenergy plants	950	4,220
Geothermal power plants	20	120
Total	**10,900**	**26,000**

Source: Cabinet of Ministers[16]

To financially stimulate the development of renewable energy sources in Ukraine, the Green Tariff, or special feed-in tariff, was introduced in 2009 via the Law of Ukraine On Electricity.[12] The Green Tariff scheme will be in place until 1 January 2030. The tariff is applied to almost all alternative energy sources (except for blast furnaces and coke gas, and hydropower plants of more than 10 MW). The Green Tariff can be applied to both legal entities (industrial plants) generating energy from all types of renewable energy and private households generating wind and solar energy. New construction projects, as well as existing renewable energy objects, are eligible for the Green Tariff.[17] The data on the renewable energy facilities operating under the Green Tariff as of the end of 2017 are shown in Table 4.

Table 4.
Renewable energy facilities operating under the Green Tariff

Renewable energy type	*Total number of facilities*	*Installed capacity (MW)*	*Electricity generation (GWh)*	*Electricity generation (%)*
Wind energy	20	465	974	46
Solar power	193	742	715	34
Small hydropower	136	95	212	10
Biomass	6	39	101	5
Biogas	21	34	94	5
Total	**376**	**1,375**	**2,096**	**100**

Source: SAEE[6]

Note: excluding Crimea PS.

The regulatory authority in Ukraine, the National Commission for State Energy and Public Utilities Regulation (NCSEPUR), establishes Green Tariffs separately for each renewable energy producer, for each energy facility and for each type of renewable energy, as well as a single Green Tariff for all private households generating wind or solar energy.[12,17] The tariff considers construction costs, maintenance and the rate of return for the electricity producer. The tariff cannot be lower than the guaranteed minimum Green Tariff, which is set based on the retail electricity tariff fixed in Euros as of January 2009 and the Green Tariff coefficient (Table 5). The tariff is set by the NCSEPUR on a quarterly basis by converting the Green Tariff calculated in Euros into the national currency. Thus, fixing the size of the Green Tariffs converted into Euros protects investors against possible inflation.[12]

Table 5.
Minimum Green Tariff rates for renewable energy producers

Type of alternative energy sources	*Capacity of power stations and other mitigating factors*	*Minimum "green" tariff (Euro cent per kWh) for power plants commissioned*				
		1 July 2015 – 31 Dec 2015	1 Jan 2016 – 31 Dec 2016	1 Jan 2017 – 31 Dec 2019	1 Jan 2020 – 31 Dec 2024	1 Jan 2025 – 31 Dec 2029
Wind power	Units of up to 600 kW	5.82	5.82	5.82	5.17	4.52
	Units of 600-2,000 kW	6.78	6.78	6.78	6.03	5.28
	Units of more than 2,000 kW	10.18	10.18	10.18	9.05	7.92
	Private households, up to 30 kW	11.63	11.63	11.63	10.45	9.32
Solar power	Ground-mounted, up to 100 MW	16.96	15.99	15.02	13.52	12.01
	Ground-mounted, above 10 MW	16.95	15.99	15.02	13.52	12.00
	On the roofs and/or house facades	18.04	17.23	16.37	14.75	13.08
	On the roofs and/or facades of private households, up to 30 kW	20.03	19.01	18.09	16.26	14.48
Hydropower	Micro-hydropower (less than 200 kW)	17.45	17.45	17.45	15.72	13.95
	Mini-hydropower (200 – 1,000 kW)	13.95	13.95	13.95	12.55	11.15
	Small hydropower (1 – 10 MW)	10.44	10.44	10.44	9.42	8.35
Bioenergy	Biomass	12.39	12.39	12.39	11.15	9.91
	Biogas	12.39	12.39	12.39	11.15	9.91

Geo-thermal	15.02	15.02	15.02	13.52	12.01

Source: Verkhovna Rada [12]

The Government guarantees the purchase of all generated electricity, except for volumes for personal needs, and its full payment. The Law of Ukraine On Electricity introduces the liability of renewable energy producers operating under the Green Tariff for hourly imbalances (difference between the actual and scheduled production). Starting from 2020, power plants generating solar, wind and hydropower and applying the Green Tariff will have to compensate the Guaranteed Buyer up to 100 per cent of the cost of the imbalance settlement. The share of compensation to the Guaranteed Buyer covered by the renewable energy producers will be increasing by 10 per cent annually and reaching 100 per cent in 2030.[14]

The mandatory local content requirement (share of raw materials, equipment, works and services of Ukrainian origin) was cancelled by amendments to the Law of Ukraine On Electricity. However, the use of equipment of Ukrainian origin is stimulated by the relevant premium to the Green Tariff if the electricity objects (phases of construction, launching complexes) are commissioned between 1 July 2015 and 31 December 2024 – a 5 per cent premium for at least 30 per cent of equipment of Ukrainian origin and 10 per cent premium for at least 50 per cent of Ukrainian equipment.[12,17] The Ukrainian origin of equipment shall be confirmed by the appropriate certificate issued by the Ukrainian Chamber of Commerce. This premium to the tariff is not applicable to electricity objects of private households.

There are also a number of tax incentives to encourage electricity generation with renewables. The importation of the following equipment to Ukraine is exempted from customs duties and VAT:

- Equipment and materials that will be used for the production of electricity from renewable energy sources;
- Raw materials, equipment and components that will be used in the production of electricity from renewable energy sources.[17,18]

Temporarily, until 1 January 2019, the following will not be subject to VAT:

- Supply of renewable energy equipment and facilities on the territory of Ukraine.
- Import of renewable energy equipment and facilities to Ukraine that will be used for the reconstruction of existing and construction of new facilities that would produce biofuels as well as for production and reconstruction of technical and transportation vehicles consuming biofuels if such products are not produced in Ukraine and there are no similar products, equipment or facilities in Ukraine. [17,19]

Incentives for small hydropower generation include the privatization of small hydropower plants, the Green Tariff and its added premium, tax benefits and preferential access to the electricity network. According to existing legislation small hydropower plants have to be privately owned or leased.[23] According to the Law of Ukraine On Environmental Impact Assessment (2017), each small hydropower plant project should be subject to an Environmental Impact Assessment (EIA).[30] There are a number of national laws and programmes for the protection, conservation and use of natural resources, as well as international treaties, conventions and protocols that should be considered in detail when developing the EIA of a small hydropower plant project, including:

- The Law of On Environmental Protection (ed. 2017); [24]
- The Water Code (ed. 2017); [25]
- The Land Code (ed. 2018); [26]
- Convention on the Conservation of European Wildlife and Natural Habitats (1979, introduced in 1982);
- The European Landscape Convention (2006);
- The Framework Convention on the Protection and Sustainable Development of the Carpathians (2003); [27]
- The Protocol on Conservation and Sustainable Use of Biological and Landscape Diversity to the Framework Convention;[28]
- International Agreement Guiding Principles on Sustainable Hydropower Development (2013). [29]

Barriers to small hydropower development

The current regulatory framework of the country provides good opportunities for the development of small hydropower. However, among the main barriers to small hydropower development in Ukraine are:

- High bank interest rates;
- A lack of normative and technical basis of the parallel operation of small hydropower plants and regional grids;
- High prices for electricity transmission;
- Environmental issues;
- Some Government acts can prolong construction and increase costs. For example, although small hydropower plants are exempt from VAT and customs duties on the import of equipment, the list of this equipment is set by the Cabinet of Ministers of Ukraine and this privilege is granted only by a special procedure following the Government agreement. This requires receiving the correct conclusions from the Ministry but how this privilege is granted is not defined, thus eliminating transparency.[31]

In 2018, Ukraine continues to reorganize the energy sector including the electricity market. It is expected that the implementation of the Law On Electricity Market of Ukraine (2017) will expand opportunities for further development.[14] For example, the separation of distribution and supply activities in regional power companies (oblenergos) should provide easier access to the power networks that are currently exclusively controlled by oblenergos. Furthermore, the new liberalized market model will allow consumers to choose among offers on the market.

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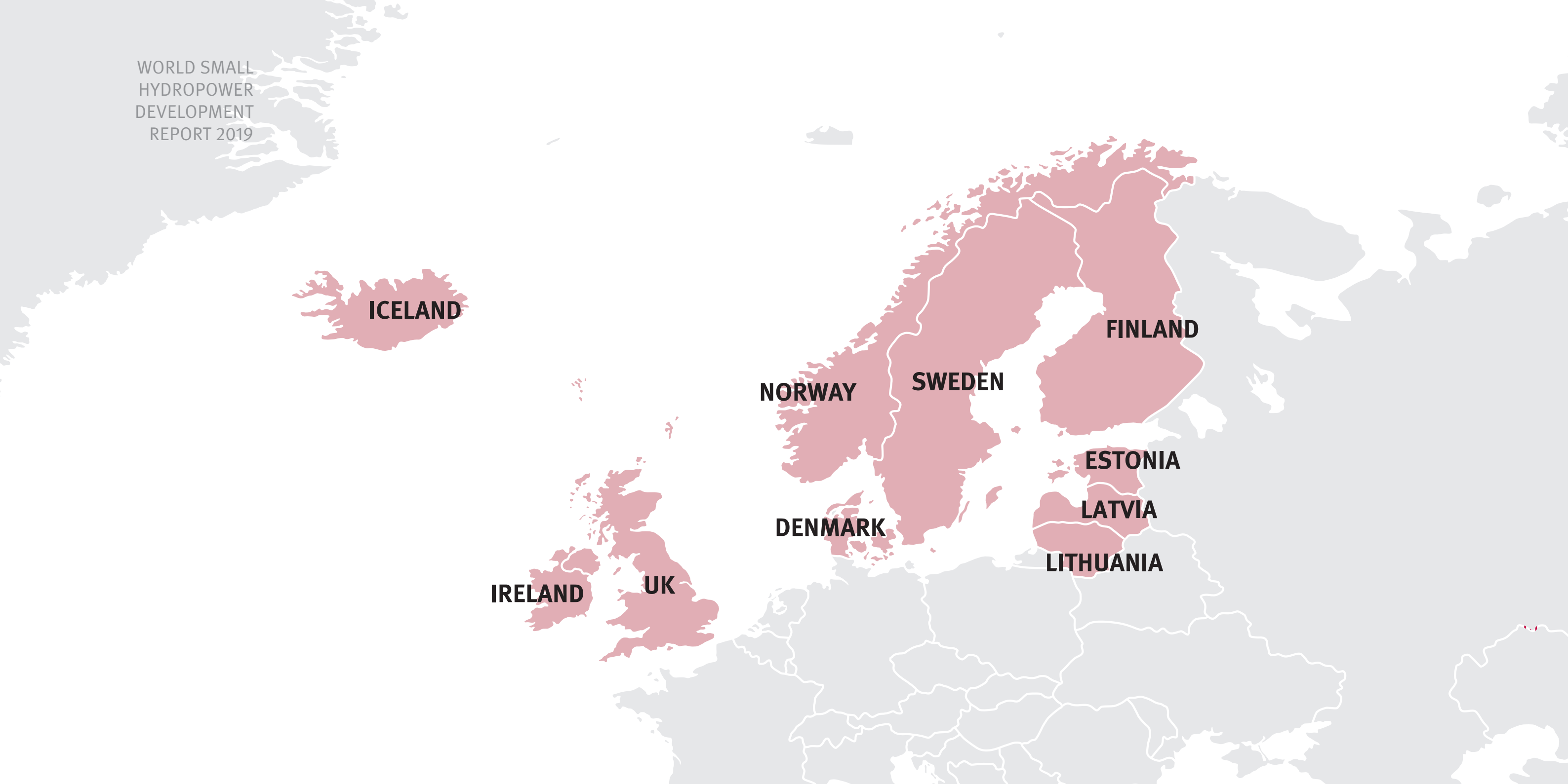

4.2 Northern Europe

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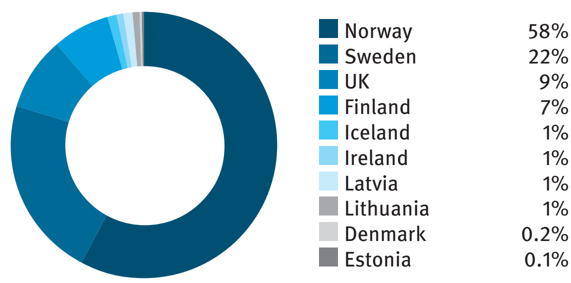
Introduction to the region

There are 10 countries in Northern Europe: Denmark, Estonia, Finland, Iceland, Ireland, Latvia, Lithuania, Norway, Sweden and the United Kingdom of Great Britain and Northern Ireland (UK). As the region is dominated by countries that are in the European Union (EU), renewable energy policy in the region is shaped according to EU directives. One of the main EU goals is to continuously increase electricity production from renewable energy sources. Consequently, this means that installed hydropower capacity in the region is slowly increasing despite the strict environmental regulations. Northern Europe is fully electrified.

The temperate climate of Northern Europe is influenced by the presence of the Gulf Stream, the North Sea and the Baltic Sea. The climate is characterized by moderate summers and winters in the southern and central parts of the region and subarctic climatic zone patterns in the northern part. The precipitation rate is usually moderate. Large areas of Northern Europe can be described as a lowland territory; still, the mountain ranges are present in Norway, Sweden, the UK (Scotland) and Iceland. The region has abundant water resources with numerous rivers and lakes. The longest rivers are the Daugava (located in Latvia, length 1,020 km, average discharge 678 m3/s), the Neman (Lithuania, 914 km, 616 m3/s) and the Glomma (Norway, 621 km, 720 m3/s). An overview of the countries in Northern Europe is presented in Table 1.

Figure 1.
Share of the regional installed capacity of small hydropower up to 10 MW by country in Northern Europe (%)



Source: *WSHPDR 2019*[3]

Norway and Sweden together account for 80 per cent of the regional share of small hydropower (SHP) up to 10 MW (Figure 1). Between the *World Small Hydropower Development Report* (*WSHPDR*) *2016* and *WSHPDR 2019*, installed SHP capacity has increased by 2.5 per cent, from 4,292 MW to 4,401 MW, mainly due to the developments in Norway and the UK (Figure 3).

Table 1.
Overview of countries in Northern Europe

Country	*Total population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Denmark	5.7	12	100	14,247	30,556	10	19
Estonia	1.3	31	100	2,885	12,176	7	35
Finland	5.5	15	100	17,175	66,199	3,159	15,634
Iceland	0.3	6	100	2,767	19,239	1,984	14,059
Ireland	4.8	37	100	10,459	28,157	530*	692
Latvia	2.0	32	100	3,095	7,340	1,564	4,386
Lithuania	2.8	32	100	3,665	3,866	1,028*	1,147
Norway	5.3	18	100	33,800	149,300	31,837	143,000
Sweden	10.1	13	100	39,991	152,600	16,181	61,700
UK	65.6	17	100	78,300	339,000	4,400*	8,400
Total	**103.4**	-	-	**206,384**	**808,433**	**60,700**	**249,072**

Source: Various 1,2,3,4,5,6,7,8,9

Note: *Including pumped storage hydropower.

Small hydropower definition

In all countries, with the exception of Ireland, the definition of SHP is up to 10 MW. The definition of SHP in Ireland is up to 5 MW (Table 2).

Regional small hydropower overview and renewable energy policy

In the Northern European countries, the distribution of installed capacity varies dramatically—from values of over 1,000 MW in mountainous Norway to under 10 MW in lowland Denmark and Estonia (Table 2). The region's total SHP potential (up to 10 MW) is estimated at 10.8 GW, of which almost 41 per cent has been developed (Figure 2).

Between the *WSHPDR 2016* and *WSHPDR 2019*, the installed SHP capacity up to 10 MW in the region increased by 108.8 MW or 2.5 per cent (Figure 3). Norway and the UK accounted for most of the capacity additions, whilst the capacities of some countries decreased as described below.

An overview of SHP in the countries of Northern Europe is outlined below. The information used in this section is extracted from the country profiles, which provide detailed information on SHP capacity and potential, among other energy-related information.

In **Denmark**, since the year 2000, the generation of renewable energy increased by 2.5 times. As Denmark is topographically unsuited for hydropower and because of existing environment constrains, the optimum hydropower capacity in the country has already been developed. All installed hydropower capacity in Denmark comes from SHP plants, which stands at 9.8 MW and has remained unchanged since 2013.

Estonia is another country in the region in which all hydropower capacity comes only from SHP plants. It is also a country with one of the lowest hydropower potentials in the region. In addition, a list of 112 rivers and their reaches was introduced as protected areas for fish populations. After the year 2020, no growth in the hydropower sector is foreseen in the renewable energy policy of Estonia. Due to the strict environmental requirements, some SHP plants in Estonia have been decommissioned since 2016. As a result, compared to the *WSHPDR 2016*, the country's installed SHP capacity decreased by almost 19 per cent. This indicates that SHP in the future will play a marginal role amongst other renewable energy sources.

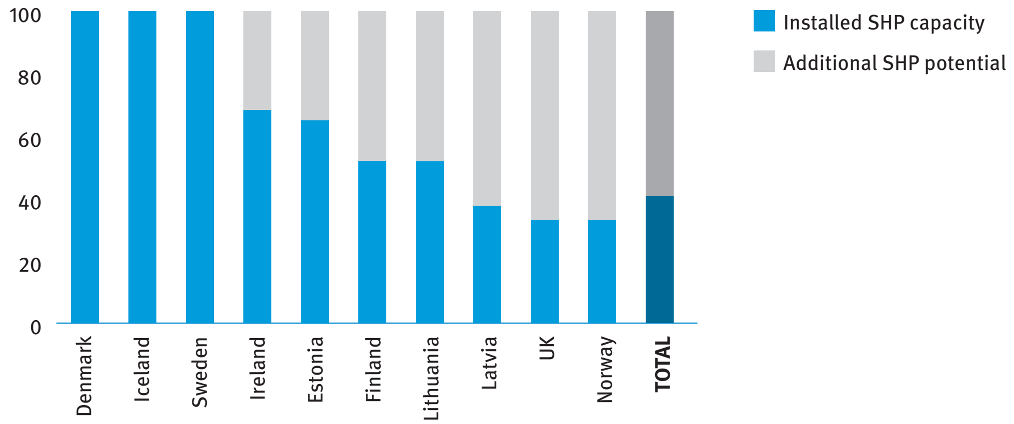
Table 2.
Small hydropower capacities in Northern Europe (local and ICSHP definition) (MW).

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed (<10 MW)*	*Potential (<10 MW)*
Denmark	up to 10	9.8	9.8	9.8	9.8
Estonia	up to 10	6.5	10.0	6.5	10.0
Finland	up to 10	312.0	600.0	312.0	600.0
Iceland	up to 10	54.8	54.8*	54.8	54.8*
Ireland	up to 5	N/A	N/A	41.0	60.0
Latvia	up to 10	28.0	75.0	28.0	75.0
Lithuania	up to 10	26.9	51.9	26.9	51.9
Norway	up to 10	2,571.0	7,803.0	2,571.0	7,803.0
Sweden	up to 10	961.0	961.0*	961.0	961.0*
UK	up to 10	390.0	1,179.0	390.0	1,179.0
Total		-	-	**4,401**	**10,805**

Source: *WSHPDR 2019*[3]

Note: *The estimate is based on the installed capacity as no data on potential capacity is available.

Figure 2.
Utilized small hydropower potential by country in Northern Europe (local SHP definition) (%)



Source: *WSHPDR 2019* [3]

Note: This Figure illustrates data for local SHP definitions. For Ireland, the data is presented for the SHP definition up to 10 MW due to the absence of data on potential capacity according to the local definition. For Iceland and Sweden, additional potential capacity is not known.

According to the most recent data available, **Finland** has 167 SHP plants with a combined capacity of 312 MW. The decrease of 2 MW compared to the *WSHPDR 2016* is due to the recent refurbishment at one of the plants that led to an increase in its installed capacity beyond the 10 MW threshold. The Government of Finland offers grants for research and investment in SHP projects. However, these grants do not include acquisition of ownership licences and feasibility studies, which makes them not feasible for small projects where installed capacity is planned to be less than 1 MW. However, even though these grants could be used for bigger projects, there has not been data on new SHP capacities installed since the *WSHPDR 2016*.

Iceland has access to large amounts of renewable energy sources, which means that the country not only has one of the cheapest prices of electricity in Europe, but also that having this amount of untapped renewable energy means that none of the renewable sources are given priority for grid connection or special subsidies. This makes SHP development difficult, as priority will be given to medium or large hydropower plants because they could be more profitable. No additional data is available regarding potential capacity for SHP, as feasibility studies and research currently are focusing on power plants larger than 10 MW. The installed SHP capacity is reported to have decreased to 54.8 MW since the *WSHPDR 2016* as a result of the upgrading of some plants.

The main incentive for the development of renewable energy in **Ireland** is the Renewable Energy Feed-In Tariff (REFIT). The REFIT 2 scheme covering onshore wind, SHP and landfill gas was opened in March 2012. In Ireland, there are approximately

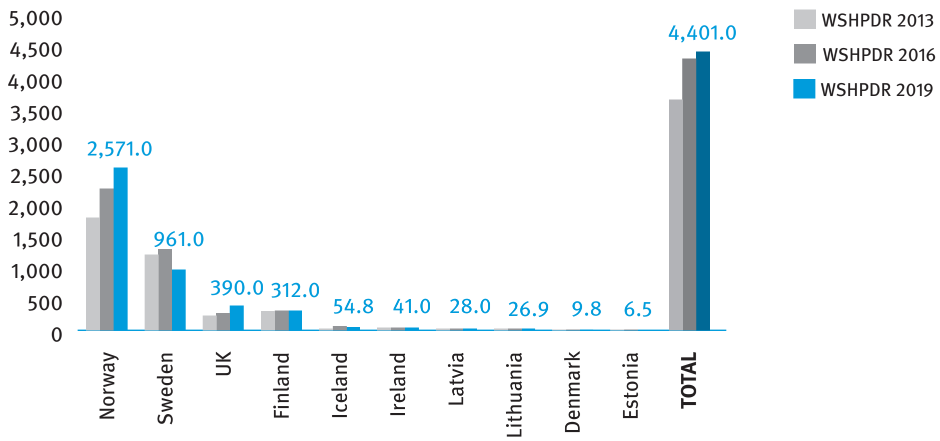
600 old mill sites that could be restored and up to 10 potential high-head sites suitable for hydropower. Still, the installed capacity of SHP in Ireland has not increased since the *WSHPDR 2016* and is reported to stand at 41 MW (for SHP up to 10 MW).

Lithuania is reported to have 26.9 MW of SHP installed capacity, coming from 98 plants. The theoretical potential of SHP is estimated at 183 MW, while the undeveloped potential, excluding protected areas is only 25 MW. Following the creation of no-go areas for the construction of hydropower plants in 2004, the development of hydropower in the country almost stopped. Between 2015 and 2017, only two new SHP plants started operation in Lithuania. Compared to the *World Small Hydropower Development Report (WSHPDR) 2016*, the installed capacity of SHP increased by 1.5 per cent. It is difficult to expect more rapid development of SHP in the near future unless the list of environmentally and culturally valuable rivers is revised.

Latvia has 147 SHP plants with a total installed capacity of 28 MW, which indicates an 8 per cent increase compared to the *WSHPDR 2016*. Only one of these SHP plants has an installed capacity greater than 1 MW. Taking into account the environmental restrictions, it is estimated that the untapped SHP potential in Latvia is up to 300 GWh. The best opportunities for development could be old water mill sites. In the late 19th century, Latvia had more than 700 water mills, but in the Soviet era SHP started to be unprofitable and by 1977 all such plants had been eliminated.

There are 1,259 SHP plants in **Norway** with a combined capacity of 2,571 MW, which contribute approximately 78 per cent of the installed hydropower capacity in the country. Compared to the *WSHPDR 2016*, the installed SHP capacity increased by roughly 15 per cent. There is still large interest in developing new SHP plants in Norway, as there are 429 licensed projects which had not yet expired or been realized, although some investments in Norway were held back either due to the project funding and budget, the lack of grid access or both.

Figure 3.
Change in installed capacity of small hydropower from *WSHPDR 2013* to *2019* by country in Northern Europe (MW)



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

Note: *WSHPDR* stands for *World Small Hydropower Development Report*.

The installed capacity of SHP in **Sweden** is 961 MW, while the potential is unknown. Compared to the *WSHPDR 2016*, the installed SHP capacity increased by 25 per cent based on more accurate data. There are at present no specific targets in relation to increasing the capacity of SHP but there is neither any limitation for expansion as long as it is aligned with the environmental regulations as well as other legislation, including dam safety and construction regulations. However, it is clear that in Sweden the development of SHP is limited and increasing capacity is possible mainly through the refurbishment of old power plants.

Due to the costs and concerns about its environmental impact, further large-scale development potential in the **United Kingdom of Great Britain and Northern Ireland** is limited, however, there is a scope for exploiting the remaining SHP resources in a sustainable way. Recent studies revealed that there is a considerable amount of financially feasible SHP sites in the country. However, the development of SHP is slow due to environmental requirements and decreasing governmental support. The current installed capacity of SHP is 390 MW, which accounts for 33 per cent of the known economically feasible potential. In comparison to data from the *WSHPDR 2016*, installed capacity has increased by approximately 42 per cent.

Feed-in tariffs (FITs) or premiums for renewable energy projects have been introduced by Denmark, Estonia, Finland, Ireland, Latvia, Lithuania and the UK. For plants greater than 5 MW, the UK offers the Renewable Obligation scheme. Although FITs exist in Finland, they do not apply to hydropower. Renewable energy plants in Norway and Sweden are supported by a joint green electricity certificate scheme. In general, the region is moving towards auction-based systems to promote renewable energy development.

Barriers to small hydropower development

All Governments of Northern European countries have introduced renewable energy policies supporting electricity generation from renewable energy sources, including support mechanisms for SHP and goals to increase the share of renewable energy by 2020. Nevertheless, the goals set for SHP development by 2020 might never be reached in some of them, because the development of SHP in the region has been significantly slowed down by the environmental requirements and legislation. Another barrier that emerged in recent years and has derailed or postponed a number of SHP projects or even led to decommissioning of SHP plants is insufficient support for the new or existing SHP schemes by the Governments.

The key barrier to SHP development in **Denmark** is its flat terrain limiting the hydropower potential, which has been almost fully developed.

In **Estonia**, the public support and social acceptance of SHP have lately been negative. Furthermore, the environmental standards for SHP schemes, including the requirement of fish pathways, increase the costs of development.

In **Finland,** there is a lack of clear rules and set deadlines in the SHP licensing process. The technical requirements for the connection to the grid are high, making it unprofitable to develop hydropower under 1 MW, while the existent measures for tax relief and the investment grants offered by the Government are not sufficient to make small-scale plants profitable. In general, other types of renewable energy, including wind power and biomass, have been prioritized. The increasing interest in other renewable energy sources such will further diminish the development of SHP.

SHP is not considered as a priority technology in **Iceland** either, with both public and private sectors currently focusing on medium and large hydropower plants, as well as wind power projects. The limited interest towards SHP translates into a lack of data on SHP potential and limited funding from the Government.

Similarly, in **Ireland** the focus of legal authorities on other renewable energy sources and the low level of public awareness concerning the development of hydropower are the main setbacks.

Development of SHP in **Latvia** is limited due to legislative requirements and a negative social stigma for hydropower. The situation is very similar in **Lithuania**. Although the public opinion concerning SHP in Lithuania is more positive, the development of the hydropower sector is very unlikely due to exceptionally strict environmental legislation.

Currently, in **Norway** there are a number of licensed SHP projects that have not been realized yet. The key barriers are the lack of project funding and the lack of grid access to some areas. On the contrary, the cost of developing new wind power has decreased in the last years and is expected to decrease further in the future.

The major barriers to increasing the installed capacity of SHP in **Sweden** are linked to the new environmental and permit regulations.

In the **United Kingdom of Great Britain and Northern Ireland**, the FITs had a small impact on hydropower development. Lowering of the FITs may further deter investors. Investors and operators must also consider environmental issues including additional features which may impact costs.

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4.2.1 Denmark

Mikael Togeby, Energy Analyses

Key facts

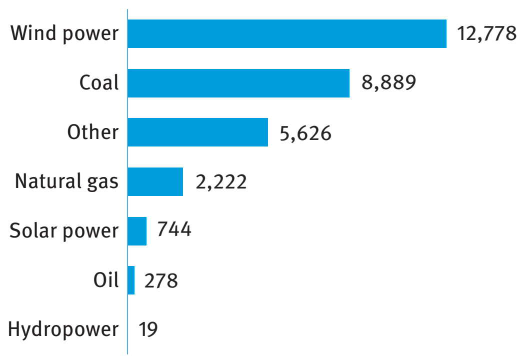
Population	5,728,010[1]
Area	43,094 km[2]
Climate	Denmark's climate is relatively warm with mild and windy winters and cool summers. The average annual temperature for the entire country varies between 6 °C and 16.4 °C. During January and February, the mean temperature is around 0.3 °C.[2, 5]
Topography	Most of the country is low and flat to gently rolling plains.[1] The highest natural peak (without man-made mounds of earth, etc.) is Møllehøj at 171 metres.[4]
Rain pattern	The average annual precipitation over land is 701 mm but varies greatly from year to year and place to place.[3, 5]
Hydrology	The longest river in Denmark is Gudenaaen at 160 km. Although Denmark is relatively rich in water resources, for the most part, it consists of flat lands with very little elevation, resulting in low flow rates in its rivers.

Electricity sector overview

In 2016, the total estimated electricity capacity was 14,247 MW: the large-scale units have 5,688 MW installed, wind power accounted for 5,245 MW, 1,839 MW are small-scale units, solar accounts for 851 MW installed, auto-producers have 615 MW and hydropower accounts for about 9 MW.[6]

In 2016, the total net electricity generation was 30,556 GWh, with imports amounting at 5,057 GWh (Figure 1). Wind accounted for 12,778 GWh, coal for 8,889 GWh, other 5,626 GWh, natural gas for 2,222 GWh, solar 744 GWh, oil for 278 GWh and hydropower 19 GWh. The electricity rate is 100 per cent.

Figure 1.
Annual electricity generation by source in Denmark (GWh)



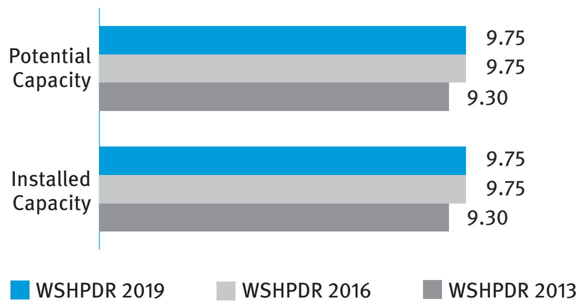
Source: Danish Energy Agency,[5] EnergieNet[6]

For the general consumption, the average electricity tariff in 2018 was DKK 0.91/kWh (approximately US$ 0.143/kWh), among the highest in Europe with Germany.[7] Denmark is also a member of the largest market for electrical energy, the Nord Pool Spot market, which offers both day-ahead and intraday markets.

Small hydropower sector overview

The definition of small hydropower (SHP) in Denmark is up to 10 MW. Since 2013, Denmark has 42 small hydropower plants with a total installed capacity of 9.75 MW (15 GWh/year).[5] The situation has remained unchanged as the total of the estimated SHP potential is 9.75 MW. Due to the flat nature of the territory and environmental constraints, there is no more potential to be developed (Figure 2).

Figure 2.
Small hydropower capacities 2013/2016/2019 in Denmark (MW)



Source: *WSHPDR 2013*,[8] ESHAIEE,[9] *WSHPDR 2016*[10]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

Renewable energy policy

As of 2017, renewable energy increased by more than 2.5 times from the year 2000. According to projections, the renewable share of the final energy consumption will reach 40 per cent by 2020, exceeding the renewable target of 30 per cent. After 2020, however, the renewable share shall remain on the same level, therefore future policymakers will be challenged to reach the government's goal of at least 50 per cent renewables share by 2030.[11]

The Promotion of Renewable Energy Act regulates the support for SHP plants.[12] As for feed-in-tariffs, the economic support scheme for SHP is of approximately 0.08 EUR/kWh (0.094 US$/kWh).[13]

Barriers to small hydropower development

The situation for SHP in Denmark has remained unchanged, for these main reasons:
Potential is small and it has already been reached;

- Residual flow requirements are judged individually for each project;[9]
- Natural barriers and the flat nature of the country.

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Estonia

4.2.2

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Key facts

Population	1,318,705[1]
Area	45,227 km^2[2]
Climate	Estonia has a temperate climate in the transition zone between maritime and continental climates. Estonia has four seasons of nearly equal length and moderate winters and cool summers. The average annual temperature is between 4.3 °C and 6.5 °C. The average air temperature in January is –6 °C to –7 °C in central and eastern Estonia and –2 °C to –4 °C in the West-Estonian Archipelago. The coldest month is February. The average temperature in July varies between 16.0 °C and 17.4 °C.[2]
Topography	Estonia has flat territory, where highlands and plateau-like areas alternate with lowlands, depressions and valleys. The bases of the highlands usually lie at 75-100 metres above sea level. The highest point is Suur Munamägi Hill at 317 metres. The West-Estonian Lowland is a swampy plateau, with limestone hills up to 20 metres high. Off the Estonian coast there are 1,521 islands. Estonia is a green land with forests covering 55 per cent of the country.[2]
Rain pattern	Estonia has a humid climate. The average annual precipitation varies between 550 mm and 800 mm. The coastal zone receives less rainfall than the inland areas. The highest recorded total annual rainfall is 1,157 mm, with the highest recorded monthly rainfall of 351 mm and the highest recorded daily rainfall of 148 mm. The average duration of snow cover during winter is between 75 and 135 days.[2]
Hydrology	There are over 7,000 rivers and streams in Estonia but most of them are short with little water. Approximately 420 rivers are over 10 km in length and only ten of them have a length of over 100 km. Less than 50 rivers have an average discharge greater than 2 m^3/sec, and only 14 rivers have a discharge of over 10 m^3/sec. The largest rivers are: the Narva River (average discharge of approximately 400 m^3/sec), Emajõgi (72 m^3/sec), Pärnu (64 m^3/sec), Kasari (27.6 m^3/sec), Navesti (27.2 m^3/sec) and Pedja (25.4 m^3/sec). The drainage is divided between four basins: Lake Peipsi, the Gulf of Finland, the Gulf of Riga and the islands of western Estonia. There are approximately 1,200 lakes with a water area of over 1 hectare (0.01 km^2). Lakes cover 4.7 per cent of the country's territory. Only Lake Peipsi and Lake Võrtsjärv can be classified as large.[2,3]

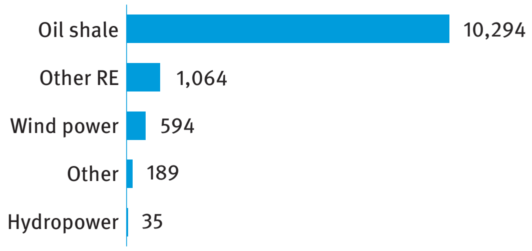
Electricity sector overview

Installed electricity generation capacity in Estonia in 2016 was 2,885 MW, including 6.5 MW from hydropower plants.[4,5] However, actual net generation capacity was lower, as it depends on repairs of the equipment and variable electricity generation from wind, hydropower and solar plants. The country's energy mix is dominated by thermal power plants, which accounted for 88 per cent of total installed capacity in 2016.[5]

In 2016, total net electricity generation was 12,176 GWh (10,417 GWh in 2015).[5] Electricity generation was predominantly from oil shale (84.5 per cent in 2016, Figure 1). Total electricity consumption in 2016 amounted to 8,385 GWh (8,137 GWh in 2015).[7] In 2016, 13.6 per cent of the country's gross consumption was covered by renewable energy.[8] The national electrification rate in Estonia is 100 per cent.

Electricity tariffs in 2016 were EUR 0.0737 (US$ 0.09) per kWh for medium size industries and EUR 0.1208 (US$ 0.15) per kWh for medium size households.[9] The Estonian electricity system forms part of a large synchronous area that consists of the electricity systems of Latvia, Lithuania, the Russian Federation and Belarus. Estonia both imports and exports electricity to Latvia, Lithuania and Finland.[6] The electricity market became entirely open for all consumers on 1 January 2013, and now the price is determined by the Nord Pool market system.

Figure 1.
Annual electricity generation by source in Estonia (GWh)



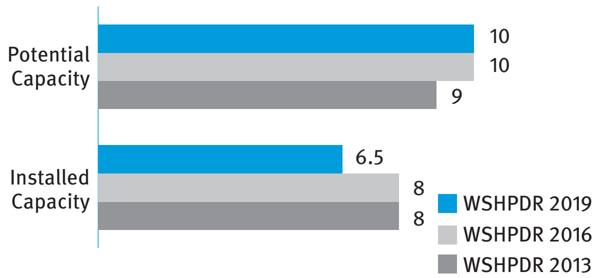
Source: Statistics Estonia[5]

Access to the electricity grid for electricity from renewable energy sources is granted based on the principle of non-discrimination. The grid operator is obliged to develop the grid to guarantee grid services for all electricity producers and to be able to connect further electricity plants to the grid. Additionally, there are a number of investment support schemes available to promote the development, installation and use of renewable energy sources installations.[10]

Small hydropower sector overview

The definition of small hydropower (SHP) in Estonia is up to 10 MW. The installed capacity of SHP in Estonia in 2016 was 6.5 MW, while the potential is estimated to be 10 MW, indicating that 65 per cent has been developed.[5,11] There are nearly 50, mostly privately owned, small hydropower plants, ranging from 4 kW to 2 MW, connected to the Estonian national grid.[11] Compared to the results of the *World Small Hydropower Development Report (WSHPDR) 2016*, the installed capacity of SHP decreased by almost 19 per cent as a result of the decommissioning of some plants due to tougher environmental objectives. The estimated SHP potential has remained unchanged (Figure 2).

Figure 2.
Small hydropower capacities 2013/2016/2019 in Estonia (MW)



Source: Statistics Estonia,[5,11] *WSHPDR 2013*,[14] *WSHPDR 2016*[15]

Note: The comparison is between the data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

Electricity generation from hydropower, however, increased thanks to the favourable conditions for hydropower energy. Thus, 35 GWh of electricity was produced by hydropower plants in 2016, which was almost 30 per cent more than in the previous year.[5]

Estonia's technically feasible hydropower potential is up to 30 MW. The country's terrain is relatively flat, so rivers have small average slopes and the energy potential of watercourses is rather moderate. Nevertheless, there are a number of suitable SHP sites, including more than 200 former water mill sites. However, due to restrictions designed to protect fish populations and the public concern for the environment, they may not be developed.[3] In line with the European Union's Water Framework Directive, a list of 112 rivers (or their reaches) with reservoirs that are preventing the migration of fish, has been introduced. This will affect SHP potential. With regard to the mitigation of the environmental impact, the conventional measures include construction of passages for migrating fish.

After the year 2020, no future growth of the hydropower sector is intended.[11] Therefore, the current economically feasible SHP potential is considered to be approximately 10 MW.[3] SHP resources are distributed across four drainage basins: Lake Peipsi (38 per cent), the Gulf of Finland (21 per cent, excluding the Narva river), the Gulf of Riga (32 per cent) and the islands of west Estonia (9 per cent).[2] The only prospective hydropower site is Omuti with a potential capacity of up to 30 MW, which is situated on the border river Narva.[3]

Renewable energy policy

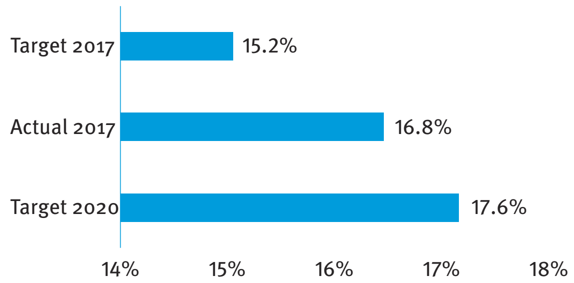
The Electricity Market Act (2003) defines renewable sources as water, wind, solar, wave, tidal and geothermal energy, as well as landfill gas, sewage treatment plant gas, biogas and biomass.[12] Electricity produced from these sources is classified as renewable energy.

As a member of the European Union, Estonia has prioritized increasing the share of renewable energy in both production and consumption in order to reduce environmental pollution and cut greenhouse gas emissions. Use of renewable energy could also promote energy saving, more efficient production and consumption, energy security, innovation in power engineering and technological development. The Development Plan for Estonia's electricity sector outlines the following:

- The need to reduce environmental emissions from power generation;
- Estonia's obligation as a member of the European Union to cut SO_2 emissions from the oil shale power plants in Narva between 2012 and 2016;
- The need for a more sustainable use of oil shale reserves;
- The aim to make electricity prices in Estonia more competitive through carbon emissions trading.[10]

The Development Plan set targets for the share of renewable energy in total electricity consumption in Estonia. In 2017, the target of 15.2 per cent was exceeded by 1.6 percentage points. The target for 2020 is set at 17.6 per cent (Figure 3).

Figure 3.
Targets for the share of renewable electricity in total gross consumption (%)



Source: Elering[16]

In Estonia, electricity from renewable energy sources is mainly promoted through a premium tariff. In addition, investment supports are available for specific types of renewable energy production technologies.[13] Subsidies are paid for electricity that is generated from renewable sources, from biomass in Cogeneration of Heat and Power (CHP) mode or in an efficient CHP mode as stated in the Electricity Market Act.[12] The cost of financing the subsidy is passed on to consumers in proportion to their consumption of network services and the amount of electricity consumed through direct lines. A subsidy of EUR 0.0537 (US$ 0.07) per kWh is paid for electricity produced from biomass in CHP mode and from hydropower, wind, solar, landfill gas, sewage treatment plant gas and biogas. A subsidy of EUR 0.032 (US$ 0.04) per kWh is paid for electricity produced in an efficient CHP mode from waste, as defined in The Waste Act, as well as peat or oil shale retort gas.[10]

Wind power and bioenergy-based combined heat and power generation has the greatest potential for renewable energy in Estonia. SHP plays a relatively marginal role.

Barriers to small hydropower development

The key barriers to SHP development in Estonia include:

- Residual flow values are fixed in the water use licensing procedure and are set on the 95 per cent fraction of the flow duration curve;
- Fish pathways are often requested making projects more expensive;
- Public support and social acceptance have been negative lately.

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4.2.3 Finland

Pihla Pietilainen, University of Helsinki; and International Center on Small Hydro Power (ICSHP)

Key facts

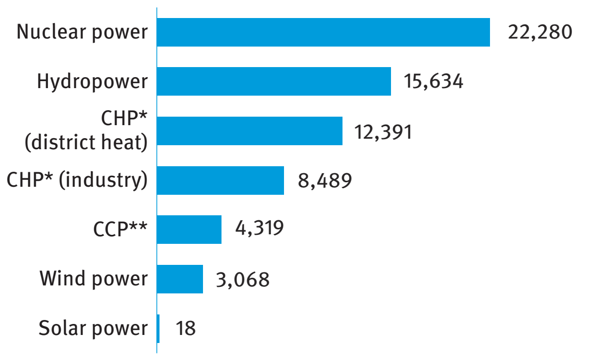
Population	5,513,130[1]
Area	390,905 km[2]
Climate	The mean annual temperature in Finland is approximately 5.5 °C in the south-west region, decreasing towards the north-east. The country is characterised by long winters, however, the temperature, in comparison to other countries located so far in the north of the globe, is considered mild. According to the research on climate change, the mean temperature increased by 0.76 °C in the 20th century. Temperature differences are most notable in January, when between the north and the south there is a variation of roughly 12 °C. The lowest temperature differences are observed between June and July, when they are approximated only 5 °C.[2] The recorded average high temperature was 31.8 °C and the low temperature was estimated at – 39.9 °C.[13]
Topography	With dense forests and low coastal plains, Finland is mostly characterised by its flat terrain, with over 60,000 lakes and numerous small islands. Its highest point is Haltiantunturi (1,328 metres) located at the edge of the Finnish border with Norway.[3]
Rain pattern	Irregular rains frequently cause abrupt changes in temperature. The annual average precipitation is between 600 mm and 700 mm, excluding the coast where precipitation is lower. More than half of the precipitation measured comes from snow. The lowest recorded annual rainfall was between 200 mm and 300 mm, while the highest was 700 mm in northern Finland and between 900 mm and 1,100 mm in the other regions of the country.[4]
Hydrology	Surface and ground water are important resources in Finland. The major rivers in the country are Kemi, Luiro, Muonio, Oulu, Teno and Torne.[3] Kemi River is the country's longest river, which flows for roughly 483 km. The river is an excellent location for harnessing hydropower. Other major rivers that are used for harnessing hydropower are the Vuoksi, the Kymi, and the Kokemäenjoki, each having 25 or more power plants.[5,10]

Electricity sector overview

At the end of 2016, the electricity production in Finland was 66,199 GWh and net electricity imports were estimated at 18,951 GWh. The proportion of imports (22 per cent of the total consumption) was the highest in history. Most of the imports came from Sweden.[24] Electricity generated from the nuclear sources accounted for roughly 34 per cent of total power generation. Hydropower was the most used renewable energy source, accounting for approximately 24 per cent of the electricity produced. Use of both wind and solar power resources increased considerably from the previous year. The annual increase for electricity produced through wind power was 32 per cent, while solar power production increased by 87 per cent. However, the proportion of energy generated through them remained low, at around 5 per cent. Figure 1 offers more details on the generation of electricity by source.[6]

Reported electricity consumption in 2016 reached 85,150 GWh. The annual change was a 3 per cent increase in comparison to the previous year. Figure 2 below offers more information on electricity consumption by sector. The industry and construction sector had the highest consumption, its share reaching 47 per cent. Only 28 per cent was used in the households and agriculture sector and 21 per cent by services and public, the rest representing transmission and distribution losses.[6]

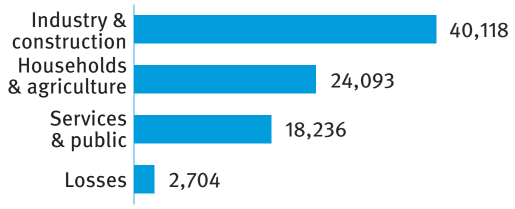
Figure 1.
Annual electricity generation by source in Finland (GWh)



Source: Statistics Finland[6]

Note: * CHP= combined heat and power, **CCP= conventional condensing power.

Figure 2.
Electricity consumption by sector in Finland (GWh)



Source: Statistics Finland[6]

Electricity prices increased by one or two per cent, depending on the consumption category, between March 2017 and March 2018. Fluctuation in Nordic electricity exchange prices and tax variation might explain the changes in price. The value-added tax (VAT) also went from 23 per cent in 2017 to 24 per cent in 2018.7 Approximately 260 companies that produce, acquire, transmit and sell electricity are represented by Finnish Energy. The organisation facilitates the management of collective labour agreements and offers training and consultancy services to its members. The organization's priority is dissemination of information and promotion of sustainable development, and it conducts multiple studies.8 Table 1 offers details on March 2018 electricity tariffs in Finland.

Table 1.
Energy prices in March 2018, Finland

Energy source	*Price (EUR/kWh (US$/kWh))*	*Annual change (%)*
Hard coal	0.040 (0.046)	1.2
Natural gas	0.049 (0.057)	9.0
Forest chips	0.020 (0.023)	-1.4
Milled peat	0.014 (0.016)	-1.1

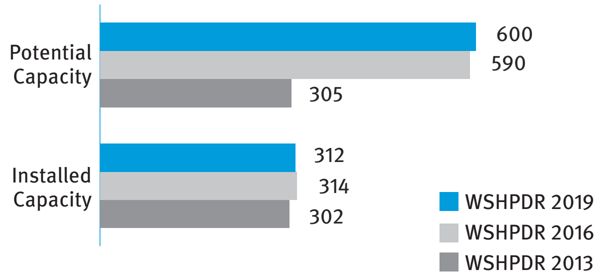
Source: Statistics Finland[7]

The main grid power lines reach 15,000 kilometres in length and are mainly used for high-transmission voltages and long-distance transmission connections. Main grid voltage is high, aiming to minimise transmission losses and reaching between 110 kV and 400 kV. There are three types of networks: high voltage (HV), medium voltage (MV) and low voltage (LV). The HV networks (110-400 kV) are 22,500 kilometres long, the MV networks (1-70 kV) measure approximately 140,000 kilometres in length and LV networks (up to 1 kV) 240,000 kilometres.[9] Electricity is distributed to all homes from the distribution network. Agriculture, commerce, industry and services could receive electricity from the main grid, HV transmission network or the distribution networks. A considerable rise in the degree of cabling was discovered in recent studies conducted by Finnish Energy. The cabling degree, which was 29 per cent in 2014, will be increasing to 44 per cent by 2019.[9]

Small hydropower sector overview

Finland defines small hydropower (SHP) as plants up to 10 MW capacity. At the end of 2016, a Finnish consulting company in the hydropower sector, Oy Vesirakentaja, published a comprehensive list of hydropower plants, including the installed capacity of each plant and their annual energy generated. According to the existent data, the installed SHP capacity is 312 MW. The decrease in SHP might be due to recent refurbishment projects at one of the plants, which lead to an increase in its hydropower capacity to 11 MW. As the plant is no longer 10 MW or below, it will be excluded to allow for efficient data comparison.10 The SHP potential was estimated at 600 MW in 2016.[11,13]

Figure 3.
Small hydropower capacities 2013/2016/2019 in Finland (MW)



Source: Oy Vesirakentaja,[10] UPM Energy,[11] *WSHPDR 2013*,[12] *WSHPDR 2016*[13]

Note: The comparison is between data from *WSHPDR 2013, WSHPDR 2016* and *WSHPDR 2019.*

Just over 50 per cent of the 167 SHP plants are under 1 MW, while the rest are between 1 MW and 10 MW in size. Electricity generated through SHP in Finland is supplied at 50 Hz to the grid. According to the Small Hydro Association in Finland, after the construction of SHP plants, the maintenance and operation costs are very low. Its production can be remotely monitored, and investment in SHP pays off in less than 10 years.14 In 2017, the Stadsfors SHP plant of 4.5 MW installed capacity started being used once again. The plant was constructed in 1926 and underwent recent refurbishment. It is now producing 12 GWh per year.[10]

The Government of Finland offers grants for research and investment in SHP projects. However, costs for acquisition of ownership licence and for the feasibility studies are not included. The demands of the water authorities are considered to be a significant part of the energy investment pillar. There are therefore support schemes for SHP that apply to the entire sector to plants that do not exceed 10 MW. These grants might not be enough for smaller projects (installed capacity under 1 MW), but they were frequently and effectively used for the construction and operation of plants between 1 MW and 10 MW.[15]

Renewable energy policy

According to the International Energy Agency (IEA), Finland is on track to achieve 38 per cent of its final energy consumption generated by the renewable energy sources by 2020, as announced in their National Energy Plan. It is predicted that biomass will have an important role in reaching the aforementioned target due to Finland's rich forestry resources.[16,17] At the end of 2017, roughly 34 per cent of Finland's energy consumption was from renewables. Hydropower, wood fuels and biomass are also counted, alongside solar, SHP and wind power.[25] Updates on the official website of Energy Finland specify that the 38 per cent target was practically reached in 2018. The goal stated in the Government of Finland's National Energy and Climate Strategy to 2030 is to increase the share of energy consumption from renewables to 50 percent in the 2020s.[18,26]

Cleantech Finland recently published a success story about the renewable energy production in Finland. The share of renewable energy in the consumption matrix is set to exceed 40 per cent due to a significant increase in the use of forest industry black liquor and other forest resources. A new target to reach 5.3 TWh of electricity from forest chips by 2020 was made official by the Director General of the Energy Authority.19 Policy schemes that might facilitate reaching this target would be comprised of a support package for small-sized wood and feed-in tariffs (FIT) for small plants to compensate for the price differences between wood chips and other alternative fuels.[20] The Government of Finland also aims to almost double wind power production by 2020, raising it to 6,000 GWh. The FIT scheme to reach the wind power target is funded from the state budget. In addition, the existent renewable energy support scheme promotes SHP. Effective renewable energy policy implementation is believed to considerably reduce Finland's dependency on energy imports.[20]

Barriers to small hydropower development

There are multiple barriers to SHP development. Some of the most significant obstacles are the following:

- The lack of clear rules and set-deadlines in the SHP licensing process;
- High technical requirements of the connection to the grid make it unprofitable to develop small scale hydropower, under 1 MW;[21]
- SHP support in the form of FITs ended in January 2012. The existent measures for tax relief and the investment grants offered are not sufficient to make plants under 1 MW profitable;
- The increased interest in wider development of wind power facilities and other renewable energy sources diminish the likelihood of SHP policy adoption.[22]

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4.2.4 Iceland

International Center on Small Hydro Power (ICSHP)

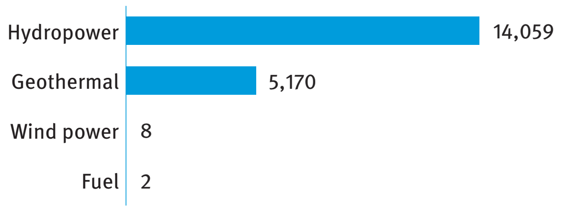
Key facts

Population	341,280[1]
Area	103,000 km[2]
Climate	The contrast between cold arctic air masses and the warm, humid Atlantic air is responsible for the unstable weather pattern in Iceland. The country has a sub-arctic maritime climate, with cool temperate influences. The mean annual temperature is approximately 4 °C. In January, the average temperature drops down to roughly -0.5 °C, while in July it reaches 11 °C. Humidity in Iceland is very high, the country gets at least 100 days of snow per year.[2]
Topography	Iceland's topography is characterized by a central volcanic plateau, which varies from 700 metres to 800 metres in elevation. The country's highest point is Hvannadalshnukur at 2,119 metres. Its lowest point is Jokulsarlon Lagoon, only reaching 146 metres.[3]
Rain pattern	The average annual precipitation in Iceland was approximated at 1,194 mm. However, the rainfall varies a lot depending on the region, ranging from a minimum of 300 mm in the north to almost 4,570 mm in the mountains.[4]
Hydrology	Iceland has numerous and diverse water resources. The main rivers in Iceland are the Pjorsa, with a length of 237 km, the Jokulsa a Fjollum at 206 km, as well as the Olfussa, the Jokulsa a Bru, the Lagarfljot, the Skjalfandafljot, the Skeidara and the Kudafljot. The country also possesses multiple lakes and waterfalls. Dettifoss is the largest cascade by volume, measuring at 44 metres. Gullfoss and Skogafoss represent other well-known waterfalls.[5]

Electricity sector overview

In 2017, total electricity generation in Iceland reached 19,239 GWh. Only 0.01 per cent of the electricity was produced from fossil fuels. The rest of the electricity was generated from hydropower, geothermal and wind power sources, with hydropower accounting for 73 per cent of the total production. A bit over 26 per cent of the electricity was generated from geothermal resources.[6] Figure 1 below offers more information on the generation of electricity by source.

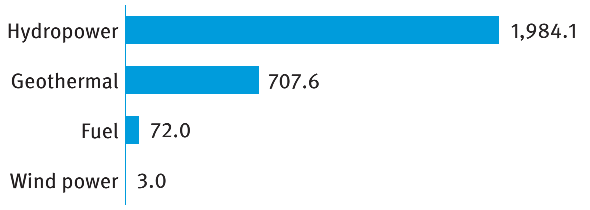
Figure 1.
Annual electricity generation by source in Iceland (GWh)



Source: Orkustofnun[6]

Total installed electrical capacity was 2,766.7 MW in 2017. Almost 72 per cent of the installed electrical capacity consisted of hydropower plants.[6] Access to electricity in the country is at 100 per cent. Figure 2 offers more information on the installed electrical capacity by source.

Figure 2.
Installed electricity capacity by source in Iceland (MW)



Source: Orkustofnun[6]

Iceland currently holds the title for the world's largest green energy producer per capita due to its hydropower and geothermal resources. Just under 100 per cent of the electricity consumed is provided through hydropower and geothermal resources. Its primary energy consumption also depends on the aforementioned sources, with roughly 85 per cent being obtained from them. As a result, the country has the highest share in the world of renewable energy in its national energy budget.[7]

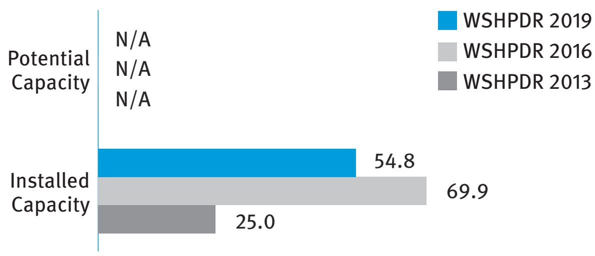
The main energy companies in Iceland are Landsvirkjun, which is owned by the Icelandic state, Orkuveita Reykjiavikur/Orka natturunnar, under the leadership of the municipalities, and HS Orka, which is under a group of Icelandic pension funds and the Canadian firm Alterra Power. Landsvirkjun is considered the largest electricity generator in the country, accounting for 75 per cent of the total electricity generation. The company is 100 per cent state-owned and was established in 1965 by the Parliament of Iceland.[7]

The country's electricity grid is one of the most reliable in the world and highly modern. Transmission lines are estimated at 3,200 km, with 77 supply points and 72 substations. The voltage of the grid's transmission infrastructure operates on ranges between 30 kV and 220 kV. Evaluations of the quality of the grid are frequently run to ensure it meets standards.8 Electricity tariffs are rising in Iceland, however, the country still has one of the lowest prices in Europe. The tariff for heavy industries in Iceland increased recently from the range of 0.030-0.035 US$/kWh to 0.035-0.040 US$/kWh.[9]

Small hydropower sector overview

The national definition for small hydropower (SHP) coincides with the definition used in the *World Small Hydropower Development Report (WSHPDR)* and refers to plants of up to 10 MW installed capacity. The current installed capacity in the country is 54.761 MW. The decrease in installed capacity may be justified by the dynamics of the hydropower sector, and, thus, refurbishment and modernization projects that resulted in the upgrading of certain SHP plants to capacity no longer within the limits of the report's definition.[10] With regards to the potential capacity for SHP, no additional data was made available, as most feasibility studies and research is currently focusing on power plants larger than 10 MW.[11] Table 1 offers more information on existing SHP plants in Iceland.

Figure 4.
Small hydropower capacities 2013/2016/2019 in Iceland (MW)



Source: *WSHPDR 2013*,[12] *WSHPDR 2016*,[13] Orkustofnun,[10] Bjornsson[11]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

There are many owners of SHP stations that sell the electricity to feed into the grid. According to the Icelandic law, all power stations, including SHP ones larger than 1 MW, must be connected to the national grid.[14]

Table 1.
Installed small hydropower plants in Iceland (kW)

Power plant	*Year*	*Capacity*
Andakill	1947	8,200
Bjólfsvirkjun	2008	6,400
Skeidfoss	1945	4,800
Gúlsvirkjun	2009	3,400
Mulavirkjun	2005	3,100
Djupadalsvirkjun I/II	2004/2006	2,800
Grimsa	1958	2,800
Koldukvislarvirkjun	2013	2,790
Pverarvirkjun	1953	2,430
Gonguskardsa	2015	1,800
Rjukandi	1954	1,680
Hvestuvirkjun	2004	1,430
Arteigsvirkjun	2005/2009	1,215
Fossarvirkjun	2015	1,200
Fossa-og Nonhornsvatn	1937	1,160
Smyrlabjargaa	1969	1,000
Ljosa	2007	980
Mosvallavirkjun	2016	890
Saengurfossarvirkjun	1976	720
Sandarvirkjun	2003	701
Tungudalsvirkjun	2006	700
Linda	2007	638
Kidarvirkjun I/II	2004	550
Reiðhjallavirkjun	1958	514
Botnsa	2001	480
Breidadalvirkjun	2012	456
Kerahnjúkavirkjun	2004	370
Glerárvirkjun	2005	307
Blaevardalsarvirkjun	1975	288
Sleitustadavirkjun	1986	218
Selarvirkjun	2007	170
Skogargerdi	2012	145
Tunguvirkjun	2001	144
Systragilsvirkjun	2005	108
Mirararvirkjun	1965	60
Rollulaekjavirkjun	2001	55
Bugavirkjun	2014	40
Total		**54,761**

Source: Orkustofnun[10]

Renewable energy policy

In Iceland, the National Energy Authority, Orkustofnun, is responsible for granting renewable energy projects licensing, in accordance with the Act on Survey and Utilization of Ground Resources. Only a proportion of the renewable energy potential of the country was developed and most recently there is an increased interest in the wind energy sector. While the wind power is not expected to account for a similar amount of electricity produced by hydropower and geothermal, Iceland's wind power potential is very high. There are also attempts to develop electricity generated through biodiesel, and this specific sector is being explored by the Government of Iceland. A few biodiesel projects were planned to commence at the beginning of 2015. The advantage of further developing the aforementioned industry is an increase in energy independence, as well as diminishing carbon emissions.[15]

All renewable energy technologies in Iceland are eligible for support schemes. Exploitation of sustainable energy resources is highly competitive in the country, however, Iceland offers grants in the field of economical energy use, thoroughly supporting the research and development sector. Funding generally comes from the state-owned National Energy Fund and all parties that propose measures for the reduction of fossil fuels use are eligible to apply. According to Article 8 of the Act Number 185 introduced in 2016, grants do not exceed 50 per cent of the estimated cost of any given project.[16]

Barriers to small hydropower development

There are several barriers to SHP development in the country, including the highly competitive renewable energy market in Iceland. The most relevant obstacles to SHP development are the following:

- The current focus and priority of both public and private sector is on medium and large hydropower plants, as well as on the development and high potential of wind power projects;
- Lack of data on SHP potential, as there are no official plans to conduct feasibility studies or future research in the sector;
- Limited funding from the state suggests there is low incentive to invest in hydropower plants equal to or below 10 MW, as larger projects would bring higher returns.[13]

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4.2.5 Ireland

Eoin Heaney, The National Trust for Ireland; and International Center on Small Hydro Power (ICSHP)*

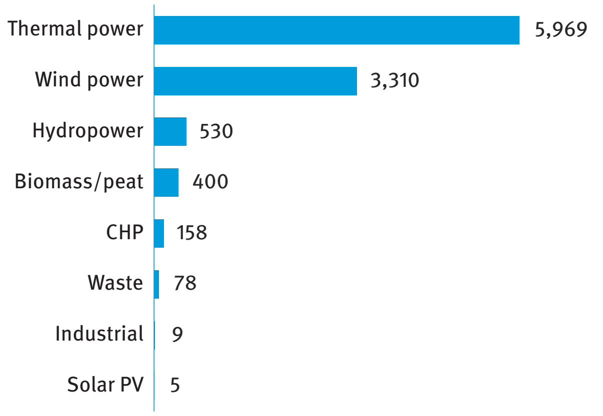
Key facts

Population	4,761,865[1]
Area	70,273 km[2]
Climate	Ireland's climate is temperate maritime, consistently humid, with mild winters and cool summers. Mean annual temperatures range between 9 °C and 10 °C, reaching 18 °C to 20 °C in the summer months.[2]
Topography	The terrain is mostly level, with rolling interior plains surrounded by rugged hills and low mountains, and sea cliffs on the west coast. At 1,038 metres, Carrauntoohil in County Kerry is the highest point in the country.[2]
Rain pattern	Annual rainfall is heaviest in the mountains, exceeding 2,000 mm. In the west of the country, rainfall averages between 1,000 mm and 1,250 mm, whereas most of the eastern half receives between 750 mm and 1,000 mm.[3]
Hydrology	Ireland has an abundance of water resources with more than 12,000 lakes and several hundred rivers. Being an island, it is surrounded by the Atlantic Ocean and the Celtic Sea.

Electricity sector overview

Electricity in Ireland is generated from multiple sources. Whilst there is still a predominant reliance on fossil fuels, renewable energy, particularly wind power, is becoming increasingly important. The installed capacity in Ireland in 2017 was 10,459 MW. The main source is thermal power, including natural gas, oil and coal, which in 2017 together accounted for 52 per cent of installed capacity (Figure 1). The installed capacity of hydropower plants was 530 MW, including the 292 MW pumped-storage hydropower plant Turlough Hill.[4]

Figure 1.
Installed electricity capacity by source in Ireland (MW)



Source: EirGrid[4]

In addition, there are Demand Side Units (DSUs) with a combined capacity of 512 MW, which are demand sites that can reduce their electricity consumption when instructed by the National Control Centre (NCC) and can thus can be dispatched by the Transmission System Operator (TSO) as if they were generators. In 2017, a number of combined heat and power (CHP), biomass and landfill gas plants were registered as DSUs. Finally, the East-West Interconnector (EWIC) linking the transmission systems of Ireland and Wales has a capacity of 500 MW in either direction. When taking into account the DSUs and EWIC, the country's total capacity increases to 11,471 MW.[4]

Total electricity production in 2017 stood at 28,157 GWh. Almost 65 per cent of electricity generation came from fossil fuels, including 52.2 per cent from natural gas, 12.1 per cent from coal and 0.5 per cent from oil. However, the share of renewable energy sources in the generation portfolio has been increasing – from 27.3 per cent in 2015 to 29.6 per cent in 2017.[5] The average daily generation system availability in 2017 was 86.7 per cent.[5] The average daily forced outage rate was 8.6 per cent.[5] The national electrification rate is 100 per cent.6 Ireland is ranked 24 out of 137 countries surveyed by the World Economic Forum in terms of reliability of electricity supply.[7]

EirGrid is the TSO in Ireland, while further transmission and distribution functions are under the control of ESB Networks Ltd. Following the deregulation of the electricity market, the Commission for Regulation of Utilities (CRU) is responsible for regulating the electricity market as well as other utilities.[8] A single electricity market (SEM) is in operation on the island

* *WSHPDR 2016* updated by ICSHP

of Ireland facilitated by the North-South interconnector. The import and export of electricity is also facilitated between Ireland and the United Kingdom of Great Britain and Northern Ireland via the EWIC.

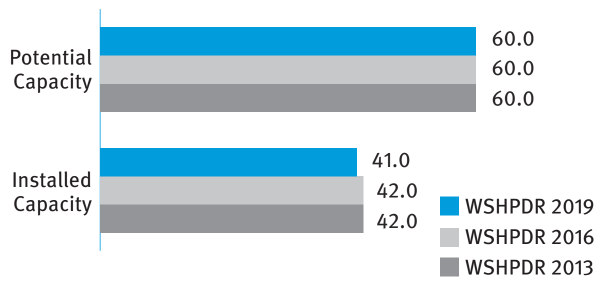
The Government's strategic plan involves the reduction of greenhouse gas emissions, as well as diversification and flexibility of supply. Over 50 per cent of the country's electricity comes from gas-fired generation, which adds to energy security concerns, particularly as 93 per cent of its gas supplies come from a single transit point in Scotland. In order to meet the ambitious renewable energy targets and improve the island's level of energy security, the country will need to successfully develop a range of large infrastructure projects.

Electricity tariffs in Ireland are deregulated and open to competition. According to Eurostat statistics, the average price for electricity in 2017 was 0.236 EUR/kWh (0.269 US$/kWh) for households and 0.124 EUR/kWh (0.141 US$/kWh) for non-household consumers.[9] Previously, until the year 2000, a monopoly was in place operated by the Electricity Supply Board (ESB).

Small hydropower sector overview

The definition of small hydropower (SHP) in Ireland is up to 5 MW. In 2017, the installed capacity of SHP up to 10 MW was 41 MW: 20 MW in the range of up to 1 MW, 21 MW in the range of 1 MW to 10 MW.10 The potential is estimated to be 60 MW, indicating that nearly 37 per cent has already been developed.[11] Between the *World Small Hydropower Development Report* (*WSHPDR*) *2016* and *WSHPDR 2019*, the installed capacity decreased by 2 per cent, while estimated capacity has not changed (Figure 2).

Figure 2.
Small hydropower capacities 2013/2016/2019 in Ireland (MW)



Source: DCCAE,10 ESHA,[11] *WSHPDR 2016*,[12] *WSHPDR 2013*[13]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

According to the National Renewable Energy Action Plan, hydropower and hydropower project means any hydro-powered electricity generating plant with an installed nameplate rating at or less than 5 MW that is connected directly to the electricity network and metered independently of any other electricity generating plant.[14] Electricity customers in Ireland who install a small generator on site are referred to as micro-generators. ESB Networks classify micro as grid-connected electricity generation up to a maximum rating of 11 kW when connected to the three-phase distribution grid (400 V) or 6 kW if connected to the single-phase distribution grid (230 V). The vast majority of domestic and agricultural customers are connected at single phase.[15]

Existing SHP capacity in Ireland is 41 MW with an estimated generation of 121 GWh in 2016. This represented approximately 12 per cent of total hydropower generation in 2015.[10] In 2010, two local authorities commissioned reports to identify the SHP potential in their counties. Twenty-seven sites were assessed in County Kilkenny using a calculation tool and producing a map illustrating potential power output. The study identified the hydropower resources that can be tapped by local community groups, landowners and local industries. Under the Kilkenny LEADER Partnership Rural Development Strategy 2007-2013, funding was available for the development of renewable energy resources in the county.[16] In 2010, five commercial and five domestic suitable sites were identified for hydropower generation, with a total annual electricity production potential of 1,232 MWh and 116 MWh per year, respectively. A further 10 commercial and 100 domestic sites that are financially viable exist in County Clare.[17]

The Irish Hydropower Association estimates that up to 600 old mill sites around the country could be developed into hydropower generation sites. A reasonable estimate (assuming that not all of these sites are redeveloped) is 25 MW of capacity with a production of up to 130 GWh per year. Additionally, 10 more potential high-head sites (500 kW each) could be developed.[18]

Renewable energy policy

Renewable energy policy is largely driven by European Union obligations, making it a core element of the Government's energy policy as a whole. This policy is built around the three pillars of:

- Security of supply;
- Environmental sustainability;
- Economic competitiveness.[19]

The policy is target driven, with a renewable energy contribution to gross electricity consumption of 40 per cent by 2020.20 The legal framework for renewable energy in Ireland is set out in the country's National Renewable Energy Action Plan, as required by Article 4 of Directive 2009/28/EC legislation.[14]

The main incentive for the development of renewable energy is the Renewable Energy Feed-In Tariff (REFIT) scheme, which is operated by the Department of Communications, Climate Action and Environment. The programme provides support to renewable energy projects over a 15-year period. The first REFIT scheme (REFIT 1) was announced in 2006 and was open for application until 31 December 2009. The REFIT 2 scheme, covering onshore wind, SHP and landfill gas, was opened in March 2012. The scheme covered projects built and put into operation between January 1, 2010 and December 31, 2015. REFIT 3 aimed to incentivize the addition of 310 MW of bioenergy capacity to the grid and was open until the end of 2015.[21]

The 2018 reference prices adjusted for inflation for the three REFIT schemes are shown in Table 1.[22]

Table 1.
2018 REFIT rates in Ireland

Technology	*Tariffs (EUR/MWh (US$/MWh))*
REFIT 1	
Large wind (> 5 MW)	69.999 (79.43)
Small wind (≤ 5 MW)	72.455 (82.21)
Hydropower	88.420 (100.33)
Biomass, landfill gas	85.964 (97.54)
Other biomass	88.420 (100.33)
REFIT 2	
Large wind (> 5 MW)	69.999 (79.43)
Small wind (≤ 5 MW)	72.455 (82.21)
Hydropower	88.420 (100.33)
Biomass, Landfill gas	85.964 (97.54)
REFIT 3	
Biomass combustion	89.671 (101.75)
Biomass combustion – energy crops	100.221 (113.72)
Large biomass CHP (> 1,500 kW)	126.595 (143.64)
Large biomass CHP (≤ 1,500 kW)	147.694 (167.59)
Large anaerobic digestion non-CHP (> 500 kW)	105.496 (119.70)
Small anaerobic digestion non-CHP (≤ 500 kW)	116.045 (131.67)
Large anaerobic digestion CHP (> 500 kW)	137.144 (155.61)
Small anaerobic digestion CHP (≤ 500 kW)	158.244 (179.56)

Source: DCCAE[22]

Currently the Department of Communications, Climate Action and Environment is developing a new support scheme for renewable electricity (RESS), which is expected to be available from 2019, subject to state aid approval. With the primary focus on cost effectiveness, the scheme will seek to promote a gradual move to market-based support for renewable energy and will be based on auctions. The policy objectives of the scheme are:

- Provision of pathways and supports for communities to participate in renewable energy projects;
- Broadening the renewable electricity technology mix;
- Delivering an ambitious renewable electricity policy to 2030;
- Increasing energy security, energy sustainability and ensuring the cost effectiveness of energy policy.[23]

Barriers to small hydropower development

The development of SHP in Ireland is constrained by a number of factors:

- SHP is not on the Government's policy radar, which has chosen wind energy as the most cost effective and feasible renewable energy solution;
- Low level of public awareness about SHP;
- Lack of accredited training courses for the installation of hydroelectric generators.[24]

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Latvia

4.2.6

Eva Kremere and Maris Klavins, University of Latvia (LU)

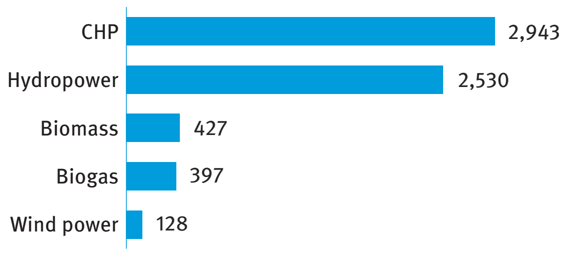
Key facts

Population	1,950,000[1]
Area	64,589 km[2]
Climate	Latvia has moderately cold winters, while summers are moderately hot. In the summer (June through August) the average temperature is 17 °C but can occasionally reach 30 °C. During spring and autumn, the weather is relatively mild, but variable, and generally humid, with an average temperature around 10 °C. Winters in Latvia usually start in mid-December and last until mid-March. The average temperature in winter is around -6 °C but can sometimes reach -25 °C.[8]
Topography	Latvia consists of a continental part in the east and the Kurzeme Peninsula (Kurland) in the west. The continental part consists of morainic uplands that are crossed by several rivers flowing to the lowlands, of which the main ones are the Daugava, Gauja and Salaca. The highest point of the country is in the Vidzeme uplands with an altitude of almost 312 metres above sea level (Gaizinkalns Hill). The continental part is separated from the peninsula in the west by the Lielupe River, which flows through the Zemgales plains. In the peninsula are the Kurzeme uplands, which are lower than the continental uplands and crossed by several rivers, of which the Venta River is the most important. The highest point in these uplands is at 184 metres above sea level. About 57 per cent of the country lies below 100 metres and only 2.5 per cent lies above 200 metres.[29]
Rain pattern	The average annual precipitation is 667 mm.[2] Rainfall is generally higher in hilly regions, with slopes facing moist air masses. The western slopes of Vidzeme Upland receive 700-800 mm of annual rainfall and the western slopes of Kurzeme Upland 650-700 mm, however, rainfall decreases along the eastern slopes. Much of the rain (70 per cent) falls in April to October, with maximum rainfall (>100 mm) occurring in August. Rainfall is lower in spring. Precipitation, as a constant snow cover, usually starts between 30 December and 5 January. The thickness of the snow cover exceeds 30 cm in most parts of Latvia; in eastern regions with a hilly topography, the snow cover is 40-50 cm deep.[9]
Hydrology	There are 12,500 rivers in Latvia with a total combined coverage of approximately 37,500 km^2. The biggest rivers are Daugava, Lielupe, Venta, Aiviekste and Gauja.[10] Depending on physical and geographical conditions, a large share of river discharge comes from either snow melt, groundwater or direct surface runoff. Approximately 50-55 per cent of the waters of the Daugava, Venta, Lielupe and Musa rivers is melted snow, while for the Gauja and Amata rivers it is 35-40 per cent.[9] The total renewable surface water resources are estimated at 16.5 km^3/year and incoming surface water resources at 18.7 km^3/year.[29]

Electricity sector overview

The electricity generation in Latvia is based mostly on large hydropower (approximately 40 per cent) and combined heat and power plants (CHP) (approximately 45per cent) with the balance coming from imports. In 2016, electricity generation in Latvia was 6,425 GWh, and, in 2017, it increased to 7,340 GWh due to the heavy rainfalls. Installed capacity is about 3 GW, while the total consumption of electricity was 3,691 GWh (Figure 1 and Figure 2). Total imports in 2017 reached 4,074 GWh and exports 4,136 GWh. Total consumption was 7,278 GWh.[30,31] The annual electricity generated in wind power plants over the 10 years from 2007 to 2016 increased from 53 GWh to 128 GWh, biomass (fuelwood) power plants and cogeneration stations from 5 GWh to 427 GWh and biogas cogeneration stations from 37 GWh to 397 GWh.[31]

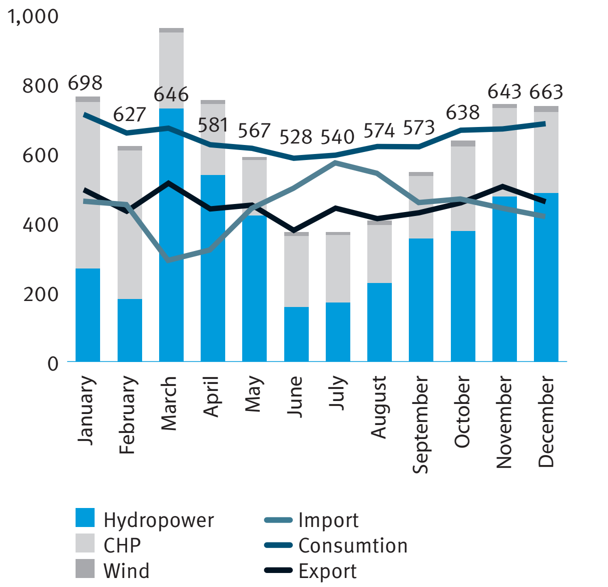
Figure 1.
Annual electricity generation by source in Latvia (GWh)



Source: Central Statistical Bureau of Latvia[31]

Note: Data for year 2016.

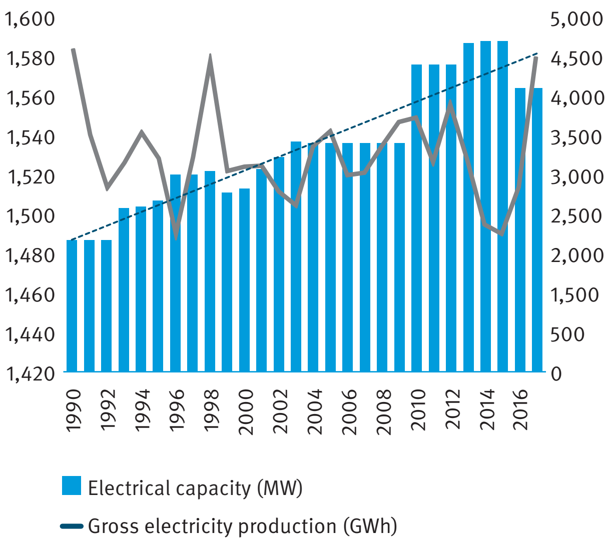
Figure 2.
Electricity generation, consumption, import and export in 2017 (GWh)



Source: Central Statistical Bureau of Latvia[30]

The greatest share of the electricity from renewable energy sources was produced in hydropower plants (80 per cent) reaching 4,386 GWh in 2017, though the installed hydropower capacity (1,564 MW) has only increased 5 per cent since 1990 (1,487 MW) (see Figure 3).[37] In 2017, hydropower plants with the capacity over 10 MW (Kegums at 264 MW, Pļaviņas at 884 MW, and Riga at 402 MW) produced a total of 4,271 GWh.[37]

Figure 3.
Electricity production and installed capacity from hydropower in Latvia (1990-2017)



Source: Central Statistical electricity Bureau of Latvia[37]

The electricity market is dominated by two state-owned companies: Latvenergo and Enefit (affiliated with the Estonian state enterprise Eesti Energia).[3] In 2017, Latvenergo generated approximately 80 per cent (5,734 GWh) of the total electricity supply. The company also ensures electric energy imports and supply to the consumers. In 2017, all of the Daugava River's hydropower plants (HPPs) produced 4,270 GWh of electricity, which is 74 per cent more than in 2016. This increase was due to the unusually large water flow. The generation of the Daugava River HPPs in 2017 was the largest since 1998 and the third largest in observed history (1966-2017). The Latvenergo Group continues the gradual refurbishment of HPPs on the Daugava River, and, by 2017, 13 out of 23 hydropower units had already been upgraded. The refurbishment is planned to be completed by 2022.[4]

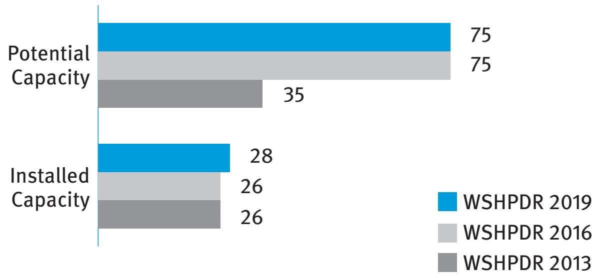
In accordance with the European Union requirements, Latvia has been moving towards an open electricity market. In 2007, the Latvia's electricity sector was opened for unrestricted competition, allowing households and other non-household consumers to choose an alternative supplier of electricity.[5,6] Compared to electricity markets of other countries that are integrated into the Nord Pool Spot exchange framework, namely Lithuania, Denmark, Estonia, Finland, Sweden, Germany and Norway, Latvia's total consumption accounts for only 1.8 per cent of total volume (approximately 425,000 GWh).[13, 33]

The power transmission network in Latvia is extensive. The main grid consists of 330 kV and 110 kV lines and substations (5,260 km). The distribution network basically consists of 20 kV and 0.4 kV lines, while 6-10 kV is for the cable network. The total length of the network is 94,701 km. The High-Voltage Network (HVN) is Latvia's transmission system operator and ensures the operation of the transmission network and the security of the electricity supply to Latvia's electricity system. HVN plans in the period from 2018 to 2027 to invest EUR 445 million in the development of the grid. There were 46 traders with licences for the electrical energy trade. Six traders were operating actively in the electrical energy market having signed contracts JSC Sadales tīkls, they are: JSC Latvenergo, LLC; Enefit, Ltd.; Inter RAO Latvia; SIA BCG Riga, Ltd.; Power Source, SIA; and Hansa Energy. The public trader licence was issued to JSC Latvenergo.[11;13] The Baltic region as a whole has interconnections with the Russian Federation (total capacity of 1,450 MW), Belarus (total capacity of 1,100 MW) and Finland (total capacity 350 MW).[13] Electricity prices in January, 2018 were 29.86 EUR/MWh (35.2 US$/MWh).[34]

Small hydropower sector overview

The definition of small hydropower (SHP) in Latvia is up to 10 MW. Installed capacity of SHP is 28 MW, while the potential is estimated to be more than 75 MW, indicating that only 37 per cent has been developed.[37] Between the 2016 and 2019 *World Small Hydropower Development Reports (WSHPDR)*, installed capacity increased by 8 per cent, while the estimated potential has not increased (see Figure 4).

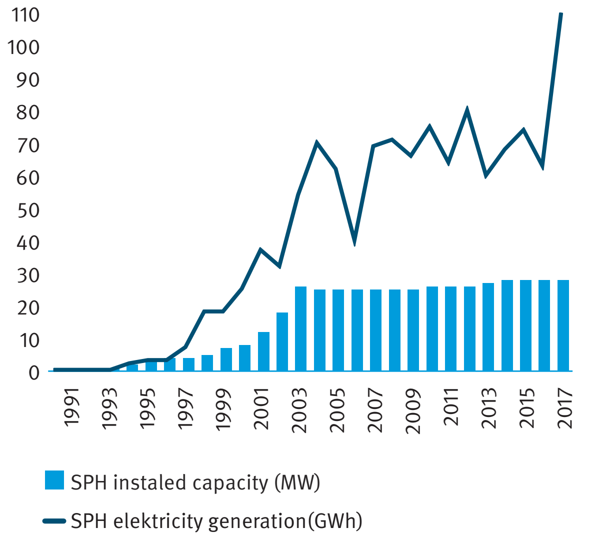
Figure 4.
Small hydropower capacities 2013/2016/2019 in Latvia (MW)



Source: Central Statistical Bureau of Latvia,[37] *WSHPDR 2013*,[35] *WSHPDR 2016*[36]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

Figure 5.
Electricity production and installed capacity from small hydropower in Latvia (1990-2017)



Source: Central Statistical Bureau of Latvia[37]

In 2017 there were 147 SHP plants with a total installed capacity of 28 MW (generating record high 110 GWh per year) (see Figure 5).[37] In Latvia, only one SHP plant exceeds an installed capacity of 1 MW. The Latvian Renewable Energy Association aims to have 180 plants with a total installed capacity of 48 MW generating 140 GWh by 2020.[12,17] The theoretical untapped hydropower potential of small and medium-sized rivers is estimated at approximately 1,160 GWh. Of these, 260 GWh are located on unusable parts of the Venta, Lielupe, Salaca and Gauja rivers. Economically feasible potential was estimated between 450 and 500 GWh, but considering all the possible constraints, environmental hydropower potential could be approximately 250-300 GWh.[20]

In the late 19th century, Latvia had more than 700 watermills. Originally, the watermills were powered by wooden waterwheels. SHP plant construction started to expand and by the end of 1926 there were 26 hydroelectric power stations with a total installed capacity of 1.5 MW and a generating capacity of 26.1 MW. During the Soviet era, SHP started to be unprofitable, and, between 1963 and 1977, all plants were eliminated, even those that were still working efficiently. All installations were dismantled and scrapped.[10] The Latvian Small Hydropower Association believes that using old watermill locations for SHP development is the best opportunity for development.[20]

There has been negative public outlook toward SHP due to the fact that electricity produced by SHP plants was relatively expensive due to the feed-in-tariff (FIT).[20]

Renewable energy policy

Directive 2009/28/EC establishes an obligation for Latvia to increase its share of renewable energy sources in the gross final energy consumption up to 40 per cent by 2020.[7,22,23,24] In order to help reaching this target, the Latvian Renewable Energy Federation has estimated feasible development of renewable energy sources for 2020 (see Table 1).

Table 1.
Potential for renewable energy sources in 2020 in Latvia

Type of RES	*Installed capacity, (MW)*	*Electricity produced, (GWh)*	*Potential capacity, (MW)*	*Potential electricity, (GWh)*
Biomass	56	195	150	760
Biogas	50	214	90	720
Wind power	75	126	500	1,500
SHP	48	140	75	220
Total	**229**	**675**	**815**	**3,200**
Large hydropower	1,522	3,000	1,522	3,000
Total	**1,751**	**3,675**	**2,337**	**6,200**

Source*:* Latvian Renewable Energy Federation[17]

The Regulations on Electricity Generation from Renewable Energy Sources (Cabinet of Ministers Regulation No. 198, initially adopted in July 2007 as Regulation No. 503) prescribes conditions for the electricity production using renewable energy sources (wind, SHP, biomass, biogas and solar). According to this regulation, producers can sell their electricity within compulsory procurement with fixed purchase prices (FIT system), if the installed electrical capacity exceeds 1 MW.

To achieve the targets from the directive 2009/28/EC and promote the production of electricity from renewable energy sources and high-efficiency cogeneration, the mandatory procurement component (MPC) is used as a support instrument. The MPC is covered by electricity users, as well as by targeted subsidies from the government. The government paid EUR 29.3 million (US$ 34.5 million) in 2014, EUR 20.3 million (US$ 23.9 million) in 2015 and EUR 978.9 million (US$ 1,154 million) in 2016.[38]

In order to prevent rapid increase of electricity prices for the households, the Ministry of Economics has already taken a number of actions, including:[39]

- Since 2012 there have been no new licences given to sell electricity in the framework of mandatory procurement;
- Fixed the MPC at 26.79 EUR/MWh (31.58 US$/MWh);
- Created a support mechanism for the energy-intensive processing companies;
- Eliminated overcompensation of the power plants by setting a maximal allowable profit margin of 9 per cent;
- A differentiation of the MPC has been made after the connection power, which has been in force since January 2018.

On 1 January 2018, a new financing model for the MPC entered into force. The change of the MPC financing model is one of the solutions developed by the Ministry of Economics within the Industrial Support Programme, whose strategic objective is to increase the volume of the industrial sector by 30 per cent in three years, with a view to increase international competitiveness of Latvia's industry sector and to reduce the costs of manufacturing for companies. This was one of the reasons why the MPC financing model changed, being dividing into two parts – the fixed power component, which depends on the voltage of the electricity connection, and the variable component, which is proportionate to the electricity consumed.[40]

Latvian industrial companies also have access to EUR 32.5 million (US$ 38.3 million) within European Union structural and investment funds programmes intended to increase energy efficiency. The Energy Efficiency Fund was also established, from which the State Development Financial Institution will support the introduction of various energy efficiency measures and solutions in Latvian companies in the coming years.[40]

Legislation on small hydropower

On 1 January 2014, the contested Natural Resources Tax Law amendments came into force. A controversial provision in the Natural Resources Tax Law states that owners of HPPs with a total capacity of the hydroelectric station installed under 2 megawatts have to pay a natural resources tax. The tax rate was EUR 0.00853 (US$ 0.01006) per 100 cubic meters of the water that has flown through the hydrotechnical structure. Another provision contested by claimants deals with a Cabinet of Ministers regulation on the procedure for calculating the amount of water that flows through a given plant. Previously, the natural resources tax did not apply to SHP plants. On 25 March 2015, the Constitutional Court ruled that these amendments are not against the constitution and are therefore in force. Moreover, the court found that said provisions were not only meant to ensure more efficient and responsible use of natural resources, but also to increase budget revenue, which, in turn, could be used to finance environmental protection measures.[16,25,26,27,28]

Latvia's SHP development is also limited due to legislative requirements, including the Cabinet of Ministers Regulations No. 27, which protects fishery resources and forbids SHP to build dams.[15,18,19]

Barriers to small hydropower development

The administrative procedures are very complicated and time consuming for SHP development. There is strong public opinion that the previous terms for SHP development were too generous and have harmed the environment. Lately there have been several developments that could hinder future SHP development:

- In 2011: a moratorium held on halting new support for SHP through 2013; in 2012, the decision was prolonged through 2018;
- In 2013: subsidized energy tax in amount of 5-15 per cent from FIT; [23]
- In 2014: new tax imposed for the water that has flown through the hydrotechnical structure is applied to SHP.[28]

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4.2.7 Lithuania

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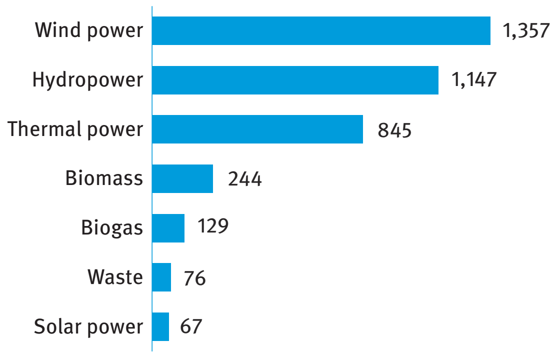
Key facts

Population	2,807,495 [1]
Area	65,300 km^2
Climate	The climate in Lithuania is transitional between marine and continental. Winters and summers are moderate and mostly wet. The average temperature in January is -5 °C and in July it is 16 °C.[2]
Topography	The country's terrain is characterized by lowlands and plains. The highest peak reaches 293.8 metres above sea level. More than a third of the country is covered with forests and more than half is arable land. Four per cent of the country's territory is covered with water; there are 22,200 rivers and 2,830 lakes. In the west, the country is bordering on the Baltic Sea and has a 100 km long coastline.[3]
Rain pattern	Precipitation patterns are mostly conditioned by the relief, the position of slopes in relation to the dominating airflows and distance from the sea. The average annual precipitation rate in Lithuania is approximately 675 mm and varies from 800-900 mm on the windward Samogitian highland slopes to 550-590 mm in the lowlands of central Lithuania. The rate of precipitation is sufficient during all seasons and is more intensive during the warm season.[4]
Hydrology	The average density of Lithuanian rivers is 1.18 km/km^2. The highest density of rivers is in the central part of Lithuania at 1.45 km/km^2, while the lowest is in the south-eastern part at 0.45 km/km^2. The highest number of lakes in Lithuania can be found in the north-eastern part of the country. There are 340 artificial ponds that have a combined area of more than 0.5 km^2 as well as few canals, but they are distributed quite equally across the country.[5]

Electricity sector overview

After the closure of the Ignalina Nuclear Power Plant in 2009, Lithuania became an electricity importing country. Every year, electricity consumption in Lithuania grows by several percentage points, whereas no growth in electricity generation has been observed in the last few years. In 2017, the amount of electricity consumed in Lithuania totalled 10.8 TWh, while total electricity generation in the same year amounted to 3.9 TWh.[6] Consequently, almost 64 per cent of electricity consumed in 2017 was imported. At the same time, the share of renewable energy sources in electricity generation has been increasing, whereas the share of thermal power has been decreasing. As a result, the total amount of produced electricity has remained approximately the same. In 2017, hydropower, including pumped storage hydropower plants, accounted for 30 per cent of the total electricity generation (Figure 1).[6]

Figure 1.
Annual electricity generation by source in Lithuania (GWh)

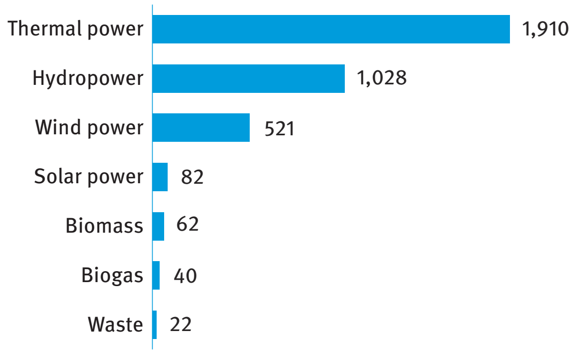


Source: Litgrid[6]

Total installed capacity of all power plants in the Lithuanian power system in 2017 was 3,665 MW, of which thermal power accounted for 52 per cent, hydropower (including the 900 MW Kruonis pumped storage plant) for 28 per cent, wind for 14 per cent, solar and biomass for 2 per cent each and biogas and waste for 1 per cent each (Figure 2).[6] The installed capacity has decreased compared to the *World Small Hydropower Development Report (WSHPDR) 2016* mainly due to the decrease in the use of thermal power plants in the country.

In line with the European Union (EU) directive 2009/72/EC outlining the common rules for the internal market in electricity, the electricity sector in Lithuania was liberalized. The public companies responsible for the production, transmission and distribution of electricity were established in 2010. The three biggest power plants in Lithuania, which generate approximately 50 per cent of all electricity in the country and are state-owned, are: Kaunas hydropower plant, Kruonis pumped storage power plant and Lithuanian power plant (a thermal power plant in Elektrėnai).[6,7,13] All small renewable energy power plants are privately owned. Lithuania is fully electrified.

Figure 2.
Installed electricity capacity by source in Lithuania (MW)



Source: Litgrid[6]

After gaining independence, Lithuania inherited a strong dependence on gas from the Russian Federation and the joint electricity network from the Soviet era. In the last five years, significant steps towards energy independence and security were taken, including finishing three strategic projects -- the international electricity interconnections with Sweden (NordBalt) and Poland (LitPol Link) and construction of the liquefied natural gas terminal in the Klaipėda Seaport.[13] In the latest edition of the National Energy Independence Strategy, approved by the Seimas of Lithuania in 2017, the Government set an ambitious target of reaching energy independence and the 80 per cent share of renewable energy sources in total electricity production for Lithuanian consumers by 2050.[8]

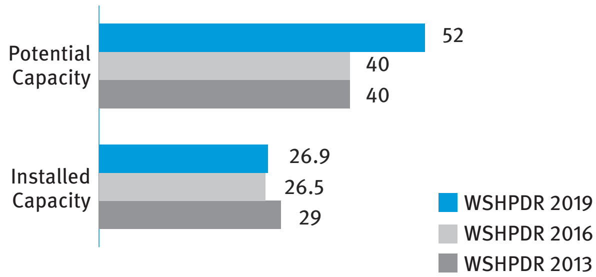
The electricity network that Lithuania inherited from the Soviet Union was modern and provided electricity to all consumers even in case of an accident. Currently, a 330-110 kV power transmission grid of Lithuania includes 234 transformer substations and switchyards as well as 6,687 km of power transmission lines. The transmission grid of Lithuania, besides NordBalt and LitPol Link, is also well connected with the power systems of neighbouring Latvia, Belarus and Kaliningrad Region.[6]

The supervision of the energy sector in Lithuania is carried out by the National Commission for Energy Control and Prices (NCC). NCC is an independent national regulatory authority (according to EU law) regulating activities of entities in the energy sector. Every month, NCC declares the average electricity market price. In January 2016, the price was 0.052 EUR/kWh (0.064 US$/kWh) without VAT, which is 27.7 per cent higher compared to the same period in 2015.[9] The monthly average market price of electricity is applied to the producers of electricity from renewable energy sources via the support mechanism through Public Service Obligations (PSO). From the budget of PSO, the producer receives a payment for the difference between the fixed feed-in-tariffs for electricity from the renewable energy sources and the price of sold electricity.[9] Currently, the electricity rate for end users in Lithuania stands at 0.113 EUR/kWh (0.139 US$/kWh).[10]

Small hydropower sector overview

In Lithuania, hydropower plants with installed capacity of less than 10 MW are classified as small hydropower (SHP) plants. According to Litgrid, in 2017 there were 98 SHP plants in operation in Lithuania, with a total installed capacity of 26.9 MW.[6] The theoretical potential capacity of SHP in Lithuania is 183 MW, however, the remaining potential available for hydropower development, excluding protected areas is only 25 MW.[12] Compared to the *World Small Hydropower Development Report (WSHPDR) 2016*, the installed capacity of SHP increased by 1.5 per cent, whereas the potential increased by 30 per cent (Figure 3). Such a change in the potential capacity is due to access to more accurate data (Figure 3).

Figure 3.
Small hydropower capacities 2013/2016/2019 in Lithuania (MW)



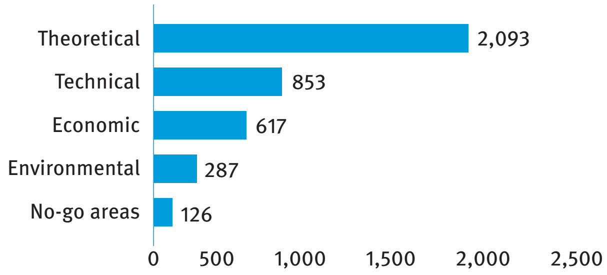
Source: Litgrid,[6] Punys et al.,[12] *WSHPDR 2016*,[13] *WSHPDR 2013*[20]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

Annual generation of electricity from SHP is approximately 100 GWh, accounting for 2.6 per cent of the total electricity generation in Lithuania.[11] The theoretical, technical, economic and environmental potentials for SHP in Lithuania in terms of electricity generation are shown in Figure 4. The figure also shows the remaining potential taking into account the no-go areas for hydropower development. These no-go areas were created in 2004 when the amendment to the Water Law was adopted, listing 170 rivers and their stretches as no-go areas for hydropower based on their environmental and cultural value. This leaves only approximately 30 rivers suitable for SHP development, which is no more than 6 per cent of the theoretical potential.[12] As a result, from 2007, the development of hydropower in Lithuania almost stopped.

In Lithuania, there is no water tax and the use of water is free of charge for hydropower plants. Only at the beginning of the whole permit process, developers of SHP plants have to apply to the Environmental Protection Agency for the special use of water. Afterwards, the process continues with a full Environmental Impact Assessment (or screening for Environmental Impact Assessment), planning and plant design permissions, construction licence, etc., and ends with an agreement on power generated from the renewable sources. The entire process can take up to 25 weeks.

Figure 4.
Electricity generation potential of small hydropower in Lithuania (GWh)



Source: Punys et al.[12]

There are no off-grid SHP plants in Lithuania. Every new plant must sign an agreement to sell electricity to the national grid. The SHP market in Lithuania is relatively small, nonetheless, some of the owners of SHP plants also have a secondary SHP plant refurbishment business. There are also cases of owners of such plants who designed their own plants, including hydropower turbines. Many of such owners established the Lithuanian Hydropower Association 20 years ago.[11]

During the period from 2015 to 2017, only two new SHP plants started operation in Lithuania.[6,13] It is difficult to expect more rapid development of SHP in the near future unless the list of environmentally and culturally valuable rivers is revised. According to the National Renewable Energy Action Plan, which is based on the commitments of Lithuania to fulfil the requirements of the Directive 2009/28/EC on the promotion of the use of energy from renewable energy sources in the EU, Lithuania has until 2020 to increase the installed capacity of SHP by 13 MW.[14] However, it is strongly doubtful that even a further 6 MW of SHP will be developed by then.

Although the public opinion concerning SHP in Lithuania was always positive, and up to 10 per cent of all generated electricity in Lithuania could be produced by SHP, subsidies and public support remain very limited, with most of the funding for SHP projects coming from the private sector. For example, in 2013, of all investments into the renewable energy sector, 47.3 per cent was loans from banks, only 2.4 per cent was support from the EU and 0.2 per cent from regional and national subsidies.[15] There is a possibility to receive funding from EU structural and investment funds if a heritage site (e.g., an old water mill) is being refurbished. However, if the theoretical mill were to be located on one of the environmentally and culturally valuable rivers there would be no possibility to rebuild the mill's reservoir.

The Renewable Energy Resources Law of the Republic of Lithuania guarantees a simplified authorization procedure for all new renewable energy plants with an installed capacity not exceeding 350 kW, except for hydropower. This simplified procedure is available only to hydropower plants without reservoirs.[16]

The fixed tariff support scheme for electricity generation from all renewable energy sources in Lithuania represents a mixture of a feed-in-tariff and a feed-in premium. As of April 2018, the fixed tariff for small hydropower was 0.059 EUR/kWh (0.073 US$/kWh).[17] As mentioned above, the electricity producer in Lithuania is paid the difference between the fixed feed-in-tariffs for electricity from renewable energy sources and the price of sold electricity. This means that the level of support depends on the electricity market conditions. This support tariff is guaranteed for 12 years starting from 2011. For new SHP plants, a fixed tariff and promotional quotas are distributed via auctions. Producers compete and those offering the least fixed tariff win. So far, only three SHP plants have received support through this mechanism.[18] Generally, the fixed tariff tends to decrease year by year, and, as a result, the payback period for SHP plants can now reach several decades.

Renewable energy policy

Renewable energy policy in Lithuania is shaped according to two EU directives: Directive 2006/32/EC on energy end-use efficiency and energy services and Directive 2009/28/EC on the promotion of the use of energy from renewable sources. The key documents that are governing the development of the renewable energy sector in Lithuanian are: Renewable Energy Resources Law (2011), National Energy Strategy (2007) and National Renewable Energy Strategy (2010) together with its Action Plans.

According to Eurostat, Lithuania in 2013 reached a 23 per cent share of renewable energy in gross final energy consumption, which was the goal set for 2020.[19] Therefore, the renewable energy policy of Lithuania can be described as successful. Although Lithuania has ambitious plans to have a green energy sector and become energy independent by 2050, the plans are based on the rapid development of wind, sun and biomass energy.[8]

In the National Climate Control Policy Strategy (2012) and National Energy Independence Strategy (2012) the development of the country's hydropower potential is stated as a priority. Nonetheless, the National Energy Independence Strategy specifies that only the part of hydropower potential that is not adversely affecting the environment should be developed. The Renewable Energy Resources Law of the Republic of Lithuania set the goal for the installed capacity of hydropower to reach 141 MW in 2020 (excluding pumped storage hydropower plants).[16] This means that today the untapped potential of hydropower in Lithuania is only 13 MW. Furthermore, the Renewable Energy Resources Law is promoting dam-less hydrokinetic hydropower technology as more environmentally friendly. So far, there are no hydrokinetic power plants operating in Lithuania.

As Lithuania does not foresee the development of large hydropower in its renewable energy policy, in all the above-mentioned laws and strategies, when the development of hydropower is mentioned, it always refers to SHP. The plan for the development of SHP in Lithuania is best reflected in the National Renewable Action Plan. The Government guaranties the fixed/feed-in tariff for hydropower plants and has some additional incentives for SHP plants with very small capacities (<30 kW), but nevertheless limits the development of SHP with one of the strictest packages of environmental laws in the EU.[12, 17]

Barriers to small hydropower development

Lithuania is a lowland country and its hydropower resources are not abundant, however, the large part of the hydropower potential remains untapped. Over more than 100 years of operation, hydropower in Lithuania has proved to be a reliable, efficient and safe source of electricity. Nevertheless, the development of SHP in Lithuania is hindered by the strict environmental regulations.

The key barriers to SHP development in Lithuania are:

- Political – the package of environmental laws in the country is stricter than the adopted EU directives on this matter. The list of environmentally and culturally valuable rivers contains 170 rivers and their stretches, which are no-go areas for hydropower development. This leaves only approximately 30 rivers suitable for SHP, i.e. not more than 6 per cent of the theoretical potential.
- Financial – the majority of investment into the SHP sector comes from bank loans. This, together with the continuously decreasing fixed/feed-in tariff, prolongs the payback period, which creates unsuitable conditions for the investors.

These are the reason why in Lithuania, since 2004, only 30 small hydropower plants have been commissioned, at a rate of 2.1 per year.[11]

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4.2.8 Norway

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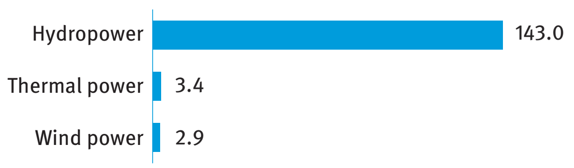
Key facts

Population	5,258,317 [1]
Area	323,808 km^2
Climate	Norway covers 13 degrees of latitude and, therefore, has a large variety in climate and temperature. Temperatures are generally warmer along the south-west coast and colder further inland. The winter period lasts between December and February when mean temperatures can reach as low as –15 °C. Summer lasts from June to August, with average temperatures between 20 °C and 22° C. During the summer months, the northern regions experience 24-hour sunlight and temperatures can reach 30 °C and above.[3,11]
Topography	The terrain is rugged and mountainous, with the Scandes Mountains stretching the length of the country. The highest mountains are in the south, with many summits over 2,000 metres above sea level. In many areas the mountains have characteristic steep sides and flat or rounded tops. This is especially true in the south and far north where the mountains form a high and relatively flat plateau. On the western coastal sides of the plateau the mountains drop precipitously into deep fjords, whereas the eastern inland slopes of the mountains tend to be more gradual. The highest point is Galdhøpiggen at 2,469 metres.[11]
Rain pattern	There are large differences in the normal annual precipitation in Norway. West Norway experiences the largest amounts, in excess of 4,000 mm annually. In these areas, frontal and orographic precipitation dominates, and most of the precipitation is received during the autumn and winter months (September to Autumn). Convective precipitation occurs most frequently in the inner districts of Østlandet (south-east) and Finnmark (north-east). Here, summer is the wettest part of the year, and winter and spring the driest.[3,11]
Hydrology	Depending on the topography, there is a wide variety of water courses in Norway, from larger river basins in eastern and middle regions to smaller and steeper river basins in the mountainous western regions. The longest river is the Glomma, at 604 km, and the largest lake is Mjøsa, which is 362 km.[11]

Electricity sector overview

As of 1 January 2018, the installed capacity in Norway was approximately 33,800 MW. In 2017, the total generation in Norway was approximately 149.3 TWh, with 143 TWh, or 96 per cent, generated from hydropower and a combination of wind and thermal power generating the remainder (Figure 1).[3]

Figure 1.
Annual electricity generation by source in Norway (TWh)



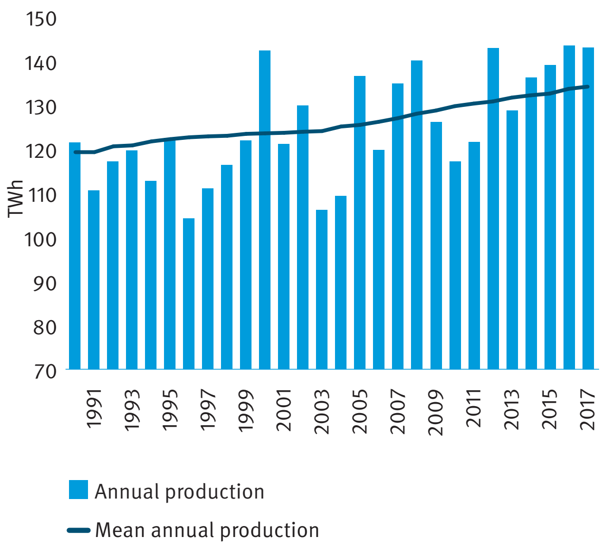
Source: Statistics Norway[3]

Due to the huge share of hydropower, the exploitable inflow is the most important input factor in the Norwegian power system. Exploitable inflow is the total amount of the inflow each year that can be utilized for power production.[4] The mean annual hydropower production of all the hydropower plants installed before the beginning of 2018 was 133.9 TWh. However, there is a significant inter-annual variation in exploitable inflow for hydropower production in the order of +/- 20 per cent, affecting the output of the plants (Figure 2).

In Norway, both power production and power consumption peak during January. The inflow, however, peaks between April and May.11 About half of Europe's total hydropower reservoir capacity, approximately 86.5 TWh, is located in Norway. Much of this reservoir capacity is used to capture inflow from the summer season for power production during the winter season, in order to meet the variability of the demand.[3]

The electrification rate is 100 per cent. Gross electricity consumption was 133 TWh in 2016. In a new report from 2018, the Norwegian Water Resources and Energy Directorate (NVE) estimated that electricity consumption can increase to 157 TWh in 2035.[14] The industry and transport sector will be the largest contributors to the growth.[11]

Figure 2.
Annual hydropower generation in Norway between 2000 and 2017 (TWh)



Source: NVE,[10] Statistics Norway[3]

All grid owners are obliged to give a connection to the grid to all new production units. The obligation to connect applies to the existing grid. In an area with many new producers but limited available capacity, the first to make a binding agreement with the grid owner is the one that gets connected. All grid owners have the possibility to require the new production units to pay a connection charge according to prevailing regulations.[5, 11]

Before 1991, power producers in Norway were obliged to cover the power demand in specific regions. The power prices were regulated and reflected the long-term marginal costs of the investments in new production capacity that had to take place in order to cover the forecasted future demand in a specific region. In 1991, a new energy act was introduced deregulating the electricity market.[4] Since then, the Norwegian power market has opened to competition and today Nord Pool Spot organizes the Nordic marketplace for trading electricity. Nonetheless, the Norwegian power industry is dominated by public ownership and a decentralized organizational structure, with approximately 10 per cent of annual production sourced from private ownership.[3, 11]

The Government regulates the transmission and distribution tariffs based on regulations laid down in accordance with the Energy Act. The NVE determines annual revenue caps for each individual licence holder. Over a period of time, the revenue shall cover the costs of operation and depreciation of the grid and, at the same time, give a reasonable rate of return on invested capital given effective operation, utilization and development of the network.[9, 11] The average price of electricity for households in the first quarter of 2018, excluding taxes and grid rent, was NOK 0.43 (US$ 0.05) per kWh. This is 23.9 per cent higher when compared to the same quarter in 2017 (Table 1).[6]

Table 1.
Electricity tariff rates in the first quarter of 2018 in Norway

Tariff type	*Tariff (US$/kWh)*	*Change in last 3 months (%)*	*Change in last 12 months (%)*
Households			
Total price of electricity, grid rent and taxes	0.13	8.1	10.3
Electricity price	0.05	18.1	23.9
Grid rent	0.03	0.0	0.0
Taxes	0.04	4.3	5.0
Households (Electricity price by type of contract. Exclusive of taxes)			
New fixed-price contracts-1 year or less*	0.04	7.5	2.8
New fixed-price contracts-1 year or more*	0.03	-19.5	-6.8
All other fixed-price contracts	0.04	-0.7	0.7
Contracts tied to spot price	0.05	20.9	31.5
Variable price (not tied to spot price)	0.06	13.8	12.1
Business activity (Electricity price. Exclusive of taxes)			
Services	0.04	18.9	26.2
Manufacturing excl. energy-intensive manu-facturing	0.04	18.8	29.1
Energy-intensive manu-facturing	0.04	9.0	1.6

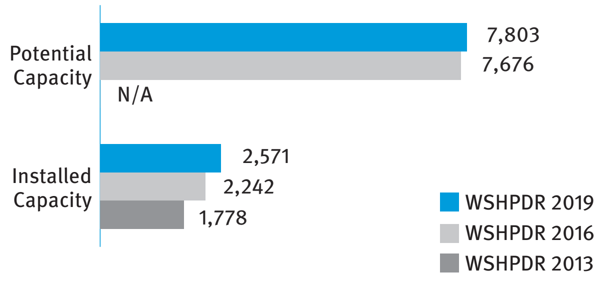
Source: Statistics Norway[6]

Note: * New fixed-price contracts are entered into the last 3 months before the measuring period, and older fixed-price contracts are entered earlier.

Small hydropower sector overview

In Norway, power plants with a total capacity less than 10 MW are classified as small hydropower (SHP) plants.11 SHP installed capacity in 2017 was approximately 2,571 MW, with an estimated additional technical potential of 5,232 MW, of which approximately 1,726 MW (33 per cent) is calculated from known projects that are under construction, have been given licences or have applied for licences.[7,8] This indicates that over 50 per cent of the known potential and approximately 30 per cent of the technical potential has been developed. The installed SHP capacity increased by roughly 15 per cent from the previous report. The increase is observed due to new SHP plants being installed, such as SHP Sandvik, which commenced operation in 2018, but also due to available and frequent data updates. SHP potential also increased by 127 MW.

Figure 3.
Small hydropower capacities 2013/2016/2019 in Norway (MW)



Source: NVE,[7] *WSHPDR 2013*,[13] *WSHPDR 2016*[11]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

As of 2017, there were 1,599 hydropower plants in the country, 1,259 (78 per cent) of which were SHP plants. Approximately 70 per cent of these are run-of-river. Combined, they contribute approximately 8 per cent of the installed hydropower capacity in Norway (Table 2). The most significant increase in new hydropower plants in Norway was in the period after World War II until the mid-1980s. Many of the SHP plants were closed down due to the interconnected net grid and economic viability of new power stations. After the deregulation of the electricity market in 1991 there was more or less stagnation in construction of new hydropower plants due to overcapacity and low prices on electricity. This has, however, changed in the last decades, which have seen an increase in the development of new SHP projects. 828 out of the 1,259 (66 per cent) SHP plants in Norway were built during the period from 2000 to 2018.[7]

Table 2.
Operational hydropower stations by size and mean annual production, 2018

Plant size	*Number of plants*	*Installed capacity (MW)*	*Electricity generation (TWh)*
<1 MW	569	182	0.78
1-10 MW	690	2,389	9.5
10-100 MW	259	9,643	43.1
> 100 MW	81	19,623	80.7
Total	**1,599**	**31,837**	**133.9**

Source: NVE[7]

Note: Data as of 1 January 2018.

There is still considerable interest in developing new SHP plants in Norway. By the end of 2017, 441 licence applications for new SHP plants were under consideration by the authorities (Ministry of Petroleum and Energy and NVE). In addition, there were 429 licensed projects which had not yet expired or been realized. The potential capacity from known projects that are under construction, have been given licences or have applied for licences is estimated at 1,726 MW.[7] While there is a technical potential for an additional 3,506 MW, this figure may be misleading as a large share of these sites are unlikely to be granted a licence or the developer has withdrawn the application.

Renewable energy policy

In 2003, the Government prepared a strategy to increase the development of SHP plants to contribute to new power generation and the development of rural areas. Many local developers of SHP plants were not familiar with the process of establishing and operating a new power plant. Focus-areas in the strategy included simplification of the licensing process, tax-based economic incentives and establishment of a certificate market for new power production.[11]

Since 1 January 2012, Sweden and Norway have had a common market for electricity certificates.[9] It is based upon the Swedish electricity certificate scheme, which has been in place since 2003. The goal is to increase the annual renewable electricity production in both countries by a combined 28.4 TWh by the end of 2020. Sweden has set an additional goal of 18 TWh between 2020 and 2030, while Norway has not set a goal for after 2020. Since its start in 2012 until 2017, the scheme contributed 20.3 TWh of new renewable energy production. The 2020 goal represents approximately 10 per cent of the current electricity production of the two countries.[11] Norway and Sweden are responsible for financing 13.2 TWh and 15.2 TWh, respectively, of the new production in the certificate system, regardless of where the new production capacity is established. The electricity certificate scheme will contribute to the achievement of the goals of the countries under the European Union's Renewable Energy Directive.[12] The common electricity certificate market is due to continue until the end of 2035. Within the electricity certificate scheme, approved power plants receive one certificate for each MWh they produce over a period of 15 years. Hence, owners of approved plants have two products on the market: electricity and certificates that can be sold independently of each other. From 2012-2018, Norwegian producers entitled to certificates received an average of approximately 15 EUR/MWh (17 US$/MWh) produced (based on the average spot price of certificates). The demand for certificates is created by a requirement under the act that all electricity users purchase certificates equivalent to a certain proportion of their electricity use, known as their quota obligation.[12]

This support scheme is technology neutral, which means that all energy sources defined as renewable energy qualify for participation in the electricity certificate market.[11] As of July 2018, about 207 new SHP plants in Norway have been granted the right to participate in the electricity certificate market which is included in the goal of 28.4 TWh. To be eligible for the market the hydropower plant must be built in accordance with the licence and commissioned after 1 January 2012.

In addition, new hydropower plants commissioned after 1 January 2004 can be certified. However, they are not included in the goal of 28.4 TWh. In Norway most of the new production developments motivated by electricity certificates will be based on the hydropower and wind power.[11]

Barriers to small hydropower development

While the country is well-known for its efficient small hydropower projects, there are certain issues that might affect future development of the sector:

- The price in the electricity certificate market adds approximately 15 EUR/MWh (17 US$/MWh) to the energy price. From the end of 2012 to the middle of 2015, the electricity price was low and sinking, before it began to rise again. At the same time, the prices for electricity certificates have been dropping and thus considered much lower than the ones before 2012.[11] The consequence of this is that many projects with a valid licence have not yet been built;
- There are areas in Norway that have problems with access to the grid, both from the local grid and from the central transmission system;
- The cost of developing new wind power has decreased in recent years and is expected to further decrease in the future;
- At the beginning of 2018 there were 429 licensed, but yet unrealized, SHP projects. In 2014, the holders of 210 licences were interviewed and it was reported that 123 of these investments were held back either due to the project funding and budget, the lack of grid access, or both.

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4.2.9 Sweden

Mathias Gustavsson, IVL Swedish Environmental Research Institute

Key facts

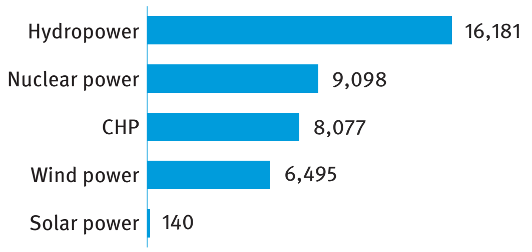
Population	10,120,242[1]
Area	450,295 km²
Climate	The climate in the south of Sweden is temperate, with cold, cloudy winters and cool, partly cloudy summers. In the north, the climate is subarctic. Summer temperatures vary little across the country, although summers are much shorter in the north. Mean July temperatures are between 15 °C and 17 °C. On the contrary, winter climate shows more variation from north to south. While the northern interior experiences severe temperatures that fall as low as -22 °C to -40 °C, in southern Sweden average January temperatures range between -5 °C and 0 °C in southern Sweden.[2,3]
Topography	The terrain is mostly flat or gently rolling lowlands with the Scandinavian Mountains in the west, which slope from the north (Norrland) to the Gulf of Bothnia. The highest point is Kebnekaise, at 2,111 metres, lying in the far north, beyond the Arctic Circle.[2]
Rain pattern	Precipitation happens throughout the year, however, the seasons with the most precipitation are summer and autumn. In the mountains, annual precipitation averages 1,500 mm to 2,000 mm. In the south-west, most wet areas receive 1,000 mm to 1,200 mm of rainfall per year. Least precipitation is observed on the small islands along the Baltic Sea and in confined valleys in the mountain regions with approximately 400 mm per year. Average annual rainfall throughout the country is at 500 to 800 mm.[3]
Hydrology	There are numerous streams, rivers and lakes in Sweden. The total length of rivers and streams is approximately 192,000 km. There are 119 main rivers, which are defined as watercourses that end in the sea and have a watershed area of more than 200 km². The longest river is the Klarälven-Göta River.[2,3,4]

Electricity sector overview

In January 2017, the total installed capacity of Swedish power plants was 39,991 MW. The energy mix was dominated by hydropower, accounting for almost 41 per cent of the installed capacity, followed by nuclear power at 23 per cent, combined heat and power (CHP) plants at 20 per cent, wind power at 16 per cent and solar photovoltaic (PV) power at 0.4 per cent (Figure 1).[5] The total installed capacity of hydropower plants was 16,181 MW. Hydropower stations are both run-of-river and reservoir types. The reservoir hydropower plays an important role for short-term balancing of the system and enables intermittent power production to be integrated into the system.

In 2016, total electricity generation in Sweden was at 152.6 TWh, with approximately 40 per cent from hydropower, slightly less than 40 per cent from nuclear power, 10 per cent from CHP plants and almost 10 per cent from wind power (Figure 2). Other sources, including solar power plants and gas turbines, contributed less than 0.01 per cent.[6] Since more than 90 per cent of the electricity comes from wind, nuclear and hydropower, the carbon emissions of Sweden associated with electricity generation are very low compared to other countries.

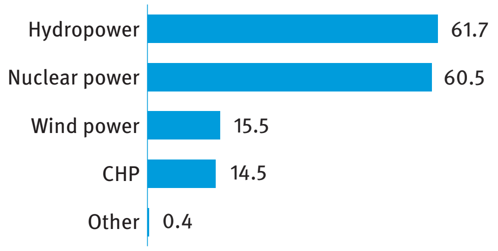
Figure 1.
Installed electricity capacity by source in Sweden (MW)



Source: Svenska Kraftnät[5]

The rate of electrification and access to the electricity grid in Sweden is effectively 100 per cent, although it would be possible to find some remote houses (not permanent living, e.g., holiday house) without access to the electric grid.[7] The per capita annual use of electricity was at 15,200 kWh in 2016.[1,6] There are relatively large differences in the power and energy demands for the summer (June to August) and winter (December to February) seasons. High power demand during cold winter days puts the highest pressure on the power system.

Figure 2.
Annual electricity generation by source in Sweden (TWh)



Source: Energy Agency[6]

The major increase in the installed capacity in recent years has come from wind power and new or converted CHP plants using biomass (Table 1). At the same time, the installed capacity of nuclear power decreased due to the closure of two reactors in Oskarshamn. The reduction in hydropower capacity is a result of the modernization of equipment and turbines.

Table 1.
Changes in installed capacity in Sweden in January 2017 compared to January 2016

	Hydropower	*Wind power*	*Nuclear power*	*PV*	*CHP*	*Total*
Installed capacity Jan 2017 [MW]	16,181	6,495	9,098	140	8,077	39,991
Change since Jan 2016 [MW]	-3	466	-611	36	157	45

Source: Svenska Kraftnät[5]

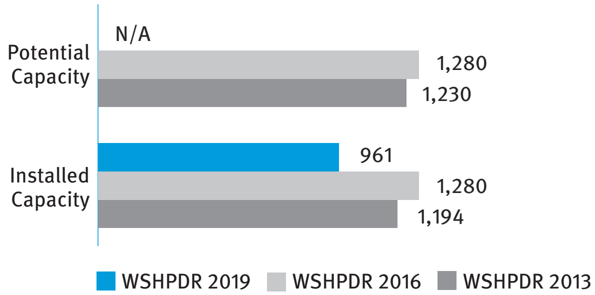
The electricity market of Sweden is deregulated and the electricity is traded on the NordPool market. Energy Markets Inspectorate is the industry regulator responsible for supervising compliance with laws and regulations. The price of the traded electricity can differ depending on operational parameters and the mix of generating capacity. There are four bidding areas (north to south) that display slightly different prices – most of the generating capacity is found in northern Sweden, while much of the demand is found in the south of Sweden. The price at the spot market (Elspot) for the Nordic and Baltic countries averaged EUR 29.41 (US$ 37.43) per MWh in 2017.[8] The average Swedish tariff for a medium size household in 2017 was EUR 0.1936 (US$ 0.220) per kWh and EUR 0.0643 (US$ 0.074) per kWh for a medium size industrial consumer. For comparison, in the European Union, the average tariff for a medium size household was EUR 0.2041 (US$ 0.230) per kWh and EUR 0.0788 (US$ 0.090) per kWh for a medium size industrial consumer.[9] For a Swedish household the cost for electricity represented about 4 per cent of the disposable income in 2015.[10]

Small hydropower sector overview

As part of the European Union (EU), Sweden defines small hydropower (SHP) as hydropower plants with an installed capacity of up to 10 MW. The old definition, which is no longer in use, classified SHP as hydropower plants with an installed capacity of less than 1.5 MW.

In 2016, total installed SHP capacity in Sweden was 961 MW.[11] The technical potential of SHP is unknown. However, it is estimated to not have been fully developed yet and a certain increase could possibly be found. However, given the current process of ensuring that SHP plants are operated according to the modern environmental regulations, there is presently some uncertainty in relation to the future development of new SHP. There is, however, an economic potential in some existing SHP plants to increase electricity generation by improving the efficiency of turbines and generators, for example. In comparison to the *World Small Hydropower Development Report (WSHPDR) 2016*, the value of installed capacity has been adjusted to 961 MW. This is 25 per cent less than the earlier assessment, which is due to access to more detailed data and is not a result of a drastic reduction of the actual installed capacity (Figure 3).

Figure 3.
Small hydropower capacities 2013/2016/2019 in Sweden (MW)



Source: Eurostat,[11] *WSHPDR 2016*,[12] *WSHPDR 2013*[13]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019.*

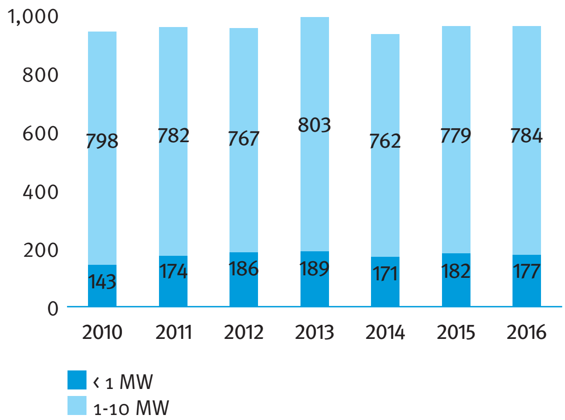
In the recent years, the installed capacity of SHP plants in Sweden has been slightly fluctuating due to refurbishment works and requirements (Figure 4).

The first hydropower plant in Sweden was built in the mid-1880s. From the beginning of the 20th century up to the beginning of the 1970s, Sweden saw a steady growth in hydropower capacity. This expansion provided a secure power supply for industry and also supported the electrification of the country. In 1975, the Government formulated a target of 66 TWh of annual contribution from hydropower to the energy balance by 1985, which was achieved in 1984.[15,16]

There are over 1,800 SHP plants in Sweden.[17] In 2016, these installations generated 3 TWh of electricity, thus accounting for approximately 5 per cent of hydropower generation and 2 per cent of total electricity generation in Sweden that year.[11]

The combined installed capacity of hydropower plants up to 1 MW was 177 MW and they produced approximately 560 GWh of electricity. More than 80 per cent (2,440 GWh) of total electricity generation from SHP in 2016 came from plants with an installed capacity between 1 MW and 10 MW.[11] There is a small share of SHP plants that are classified as auto-producers, and in 2016 they generated less than 1 per cent of electricity from SHP.[11] Most SHP plants are of a run-of-river type, hence, production is dependent on the flow in the river and these power plants have very little balancing or regulating capacity. SHP plants are more commonly found in the southern parts of Sweden, while large hydropower plants are more typical for the northern parts.[18]

Figure 4.
Installed capacity of small hydropower plants in Sweden in 2010-2016



Source: Eurostat[11]

There are three overarching goals set by the Government in relation to hydropower in Sweden. The first relates to the concession rights – water operators in Sweden should have concessions that are in line with the Swedish environmental legislation and European Union (EU) regulations. The second goal relates to the production with the aim to maintain both production and balancing capacity for hydropower in Sweden. The third goal is to ensure the efficient operation of hydropower.[15]

There are, at present, no specific government targets in relation to increasing the capacity of SHP in Sweden but there is neither any limitation for expansion as long as it is aligned with the environmental regulations as well as other legislation, including dam safety and construction regulations. There has for some years been little expansion or change in the number of SHP plants in Sweden (Figure 4). The Swedish Energy Agency has determined that the main new potential in hydropower in Sweden is found in modernizing and improving efficiency in existing hydropower plants.[12] Considering the Swedish context, this would typically be most efficient to do in large hydropower plants.

The main discussion on hydropower (both small and large) in recent years has focused on how to align existing hydropower plants with new legislation. In 2014, the Swedish Energy Agency and the Swedish Agency for Marine and Water Management presented a policy on how this could be achieved.[19] The policy sets certain guidelines and priorities for different water catchment areas. Large hydropower plants provide both the major part of the electrical energy to the power system and also the short-term regulating capacity to balance the system. SHP plants have a very limited balancing capacity.[20] Nonetheless, SHP is planned to keep contributing to domestic renewable energy production even though the percentage as compared to the total electricity generation from hydropower is small. Another motivation for maintaining SHP is that many of the plants are classified as Swedish cultural heritage.[21] At the same time, there is a documented need to improve the environmental status of many affected rivers and streams in order to comply with the Swedish Environmental Objectives linked to the UN Sustainable Development Goals (e.g., Flourishing Lakes and Streams objective) and the EU water quality directive.[22,23,24,25,26,27]

Thus, in light of the energy policy of Sweden and the processes linked to ensuring the Environmental Objectives and heavily modified water bodies, the number of SHP plants seems unlikely to rise drastically in the next ten years. However, there is a certain potential to increase the installed capacity in already existing plants through improved efficiency and upgrades in line with the government decisions on the requirements for hydropower permits.

In recent years, a number of fauna passages or bio-channels have been built around SHP plants. These have the potential to reduce the fragmentation in the river caused by hydropower dam construction.[28] However, as many of the SHP plants in Sweden are old, and new ecosystems have been established around them, stakeholders linked to the owners of the plants have raised concerns about the costs and net benefits of these installations. All stakeholders acknowledge the input to the energy system that hydropower makes, but due to, among other things, the old permits linked to many of the existing SHP plants, environmental organizations are not actively promoting small hydropower as a better alternative to large hydropower. Environmental organizations, such as *Naturskyddsföreningen* (Swedish Society for Nature Conservation), actively support environmental improvements in existing hydropower via fauna passages, its eco-labeling scheme, *Bra Miljöval* (Good Environmental Choice) and the environmental funds generated from the purchase of eco-labelled products.

Renewable energy policy

In 2016, the share of renewable energy in the Swedish energy system was 57 per cent and for electricity generation the share from the renewable energy sources was 50 per cent.[5,6] A market-based support system for renewable electricity production has been in place in the form of electricity certificates since 2003. Since 1 January 2012, Sweden and Norway have had a common electricity certificate system in order to support more cost-effective solutions and ensure higher liquidity and more actors in the market.[29] Over the period until 2020, the two countries aim to increase their production of electricity from renewable energy sources by 28.4 TWh as compared to the 2012 baseline. The joint market permits trading in both Swedish and Norwegian certificates and receiving certificates for renewable electricity production in either country. There are no feed-in tariffs or other direct support mechanisms for SHP in Sweden.

The water concessions that are linked to the hydropower stations in operation today are in most cases based on older legislation. For example, according to a government report from 2014, more than 90 per cent of all hydropower concessions were granted prior to 1983 and, thus, the concession rights are based on the Water Law of 1918 or even older legislation.[30] Many older SHP plants in Sweden have now been phased out of the Swedish green certificate support scheme. To be entitled to operate for the next 15 years, the plants are required to undergo a total refurbishment of all essential parts. Since refurbishment is very expensive and is not always economically viable for smaller plants (approximately less than 100 kW), many SHP stations could face an uncertain future.[31] The green certificate market is a technology-neutral instrument and there are no targets set specifically for new hydropower capacity. From 2007 onwards, not many new plants have been built but refurbishment is being carried out, including upgrading larger SHP plants. However, typically, there is a higher cost per produced kWh as compared to large hydropower, and the economic incentives are weak to undertake modernizations of equipment or to improve the environmental status of the affected water, especially for the large number of hydropower stations with installed capacity of less than 1.5 MW.

In March 2018, a broad political agreement was reached between the Government of Sweden and several of the parties in the opposition with the aim of addressing the uncertain situation whereby SHP plants were facing the need to re-apply for concessions linked to potentially high legal and consultancy costs. The political agreement means that a more pragmatic approach has been chosen, according to which all Swedish hydropower should operate based on modern permits, but existing power plants with old permits will have an opportunity to revise their permits instead of re-applying.[31,32] This opportunity will reduce the need for supporting documentation such as environmental impact assessments and reduce administration requirements. This could potentially mean that new SHP initiatives could be taken. Several stakeholders concerned with the existing environmental status of the water are, however, less happy with the political outcome.

The EU Renewable Directive 2009/28/EC (by 2020) has not resulted in any changes for SHP in Sweden and it is not foreseen that the next EU package "Clean energy for all Europeans" will change the situation.[33] The EU Water Framework Directive is implemented under the Swedish Law.[27] The outcome of the new guidelines and processes is currently taking place with respect to secure balancing and regulation of capacity and heavily modified bodies of waters.

Barriers to small hydropower development

The major barriers to increasing the installed capacity of SHP in Sweden are linked to the new environmental and permit regulations, in particular:

- There are costs involved in providing and generating the supporting documentation for new concession rights, and documentation requirements have been independent of the size of SHP plants;[34]
- The operationalization of the political agreement reached in 2018 on hydropower permits is under preparation, thus there are still some uncertainties on the procedures for the stakeholders, though the situation is expected to be clarified in 2019.

To summarize, the Government is committed to ensure the further operation and modernization of existing SHP plants, while at the same time addressing the challenge of heavily modified bodies of water.

Nonetheless, the present process in Sweden acknowledges the long tradition of SHP and finding solutions acceptable for the stakeholders involved.

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4.2.10

United Kingdom of Great Britain and Northern Ireland

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Key facts

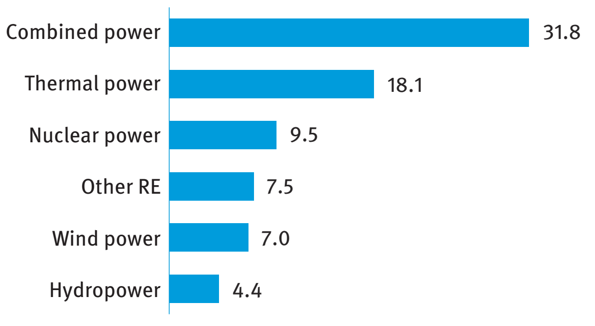
Population	65,648,054[1]
Area	248,531.52 km^2 [2]
Climate	The United Kingdom of Great Britain and Northern Ireland (UK) has a temperate climate, and the Gulf Stream ensures mild, maritime influenced weather. Temperatures range from not much lower than 0 °C in the winter months between December and February and not much higher than 32 °C in the summer months between June and August. The temperatures in Scotland are generally lower than in the other parts of the country.[3]
Topography	The UK is divided into the hilly regions of the north, west and south-west and low plains of the east and south-east. The eastern coast of East Anglia is very low lying, much of it at less than 5 metres above sea level. Of the top ten highest peaks, all are located in either Wales or Scotland. The highest point is Ben Nevis reaching 1,343 metres.[4]
Rain pattern	The mountains of Wales, Scotland, the Pennines in northern England and the moors of south-west England are the wettest parts of the country. Some of these places receive over 4,500 mm of rainfall annually making them some of the wettest locations in Europe. Other parts of the country can be very dry with the south and south-east regions receiving an annual average of less than 800 mm.[3]
Hydrology	The longest river is the Severn (354 km) flowing through both Wales and England and the second longest is the Thames (346 km)[5]. Other major rivers in England and Wales include the Humber, Tees, Tyne, Great Ouse, Mersey and Trent rivers. The river system of Scotland is largely separate from that of England. The two major rivers of the central lowland of Scotland are the River Clyde and the River Forth. The longest river in Scotland is the River Tay (188 km). As a result of its industrial history, the UK has an extensive system of canals, mostly built in the early years of the Industrial Revolution.

Electricity sector overview

Electricity infrastructure in the United Kingdom of Great Britain and Northern Ireland (UK) is well developed with a 100 per cent electrification rate. In 2016, total installed capacity was 78.3 GW. Approximately 41 per cent was from combined cycle gas turbine plants, 23 per cent from conventional thermal power plants (utilizing both coal and gas), 12 per cent from nuclear plants, 9 per cent from wind power, 6 per cent from hydropower plants (including pumped storage facilities) and a further 9 per cent from other forms of renewable energy (Figure 1).[6]

In 2016, total electricity generation was 339 TWh, of which renewable energy (including renewable thermal energy) accounted for 25 per cent. Gas powered plants dominated the generation mix, contributing 42 per cent to total generation. Nuclear provided 21 per cent, while wind and solar photovoltaic (PV) contributed approximately 14 per cent (Figure 2). Coal played a limited role, contributing only to 9 per cent of the generation in 2016. Natural flow hydropower accounted for less than 2 per cent. For electricity generated from renewable sources, wind and solar contributed more than half (55 per cent).[7]

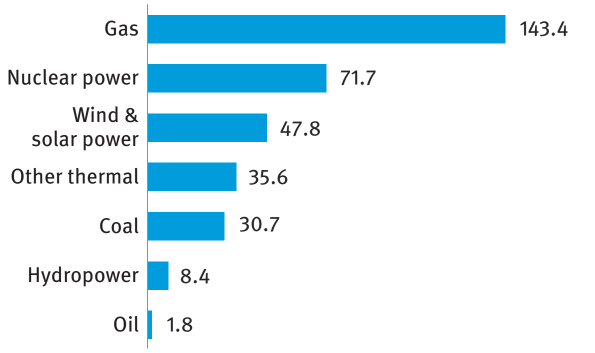
Figure 1.
Installed electricity capacity by source in the United Kingdom (GW)



Source: DUKES [6,7]

Note: To account for intermittency, small-scale hydropower, wind and solar photovoltaics capacities are multiplied by factors of 0.365, 0.43 and 0.17, respectively.[7]

Figure 2.
Annual electricity generation by source in the United Kingdom (TWh)

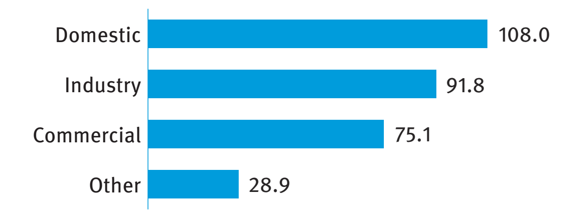


Source: DUKES[7,11]

In addition to domestic generation capacity, the UK electricity network also has four interconnectors totaling 4 GW of capacity connecting the grid with Ireland and mainland Europe: England-France (2 GW capacity), England-Netherlands (1 GW), Northern Ireland-Ireland (0.6 GW) and Wales-Ireland (0.5 GW).[9] The country was a net importer of electricity in 2016, with net imports contributing 4.9 per cent (19.7 TWh) of electricity supply.[7]

Final consumption in 2016 was 303.8 TWh, with approximately 36 per cent consumed by the residential sector, 30 per cent by the industrial sector and 25 per cent by the commercial sector (Figure 3).[6,7]

Figure 3.
Electricity consumption by sector in the United Kingdom in 2016 (TWh)



Source: DUKES [6,7,11]

Although there are many producers operating within the generation sector it is largely dominated by six companies, collectively known as the Big Six: EDF, Centrica (British Gas), E.ON, RWE nPower, Scottish Power and SEE plc. National Grid plc is responsible for the transmission network in England and Wales. In Scotland, the grid is split between two separate entities: SP Energy Network (a subsidiary of Scottish Power) is responsible for southern and central Scotland and SSE plc is responsible for northern Scotland. National Grid plc, however, remains the system operator for the whole UK grid. Nine Distribution Network Operators (DNO), operating in twelve separate regions, distribute electricity from the transmission network.[43]

Full competition was introduced into the UK electricity retail market in 1999.[12] Electricity suppliers buy electricity from the wholesale market or directly from generators and arrange for it to be delivered to the end customers, who can choose any supplier to provide them with electricity. The market is regulated by the Gas and Electricity Markets Authority, which operates through the Office of Gas and Electricity Markets (Ofgem). Ofgem issues companies with licences to carry out activities in the electricity and gas sectors, sets the levels of return which the monopoly networks companies can make and decides on changes to market rules.[13,43]

Electricity costs vary across suppliers and regions. In 2016, the average annual residential electricity unit price in the UK (across all payment types) was approximately 0.163 GBP/kWh (0.259 US$/kWh) based on an annual consumption of 3,800 kWh.[31,39] According to January 2018 data, average electricity prices of the Big Six were:

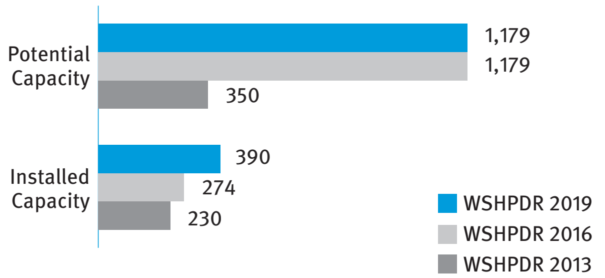
- nPower: 0.284 GBP/kWh (0.400 US$/kWh);
- British Gas: 0.217 GBP/kWh (0.306 US$/kWh);
- EDF Energy: 0.202 GBP/kWh (0.284 US$/kWh);
- E.ON Energy: 0.187 GBP/kWh (0.263 US$/kWh);
- ScottishPower: 0.175 GBP/kWh (0.246 US$/kWh);
- SSE: 0.172 GBP/kWh (0.242 US$/kWh). [32]

The UK faces particular challenges to ensure a continuing security of supply, to decarbonize electricity generation and to maintain affordability.[14] Electricity demand is expected to increase due to electrification of end-use sectors such as transport and heat.[15] Furthermore, approximately a fifth of existing plants are set to close over the coming decade and will be replaced by sources which are likely to be increasingly intermittent, such as wind, or inflexible, such as nuclear.[14,15] An analysis by the Committee on Climate Change (CCC) has suggested the need for investment in 30-40 GW of low-carbon capacity between 2020 and 2030, to replace the ageing capacity currently on the system and to meet growing demand.[16,43] Renewable generation, especially wind, can play a greater role to meet part of the future capacity expansion requirements in the power sector of the UK. In recent years, investment in wind has made good progress, with the construction of 2.6 GW of onshore capacity and 1.7 GW of offshore capacity in 2017, leading to a total installed capacity of 18.9 GW of wind power (not de-rated, see note to Figure 1) by the end of 2017.[8] The Government has introduced renewable electricity policies in order to increase the share of renewable energy (wind, biomass, solar and hydro) in the UK electricity generations (see below).

Small hydropower sector overview

In the UK, small hydropower (SHP) is generally defined as up to 10 MW.[29] According to the Department of Business, Energy and Strategy (BEIS), as of September 2017, there was a SHP installed capacity of 390 MW, with an estimated additional, financially viable, potential of up to 789 MW.[25,26,30] This would suggest that approximately 33 per cent of SHP potential has been developed. It is worth noting, however, that the estimated potential figure is based upon studies with minimum installed capacity limits meaning that sites with capacities below these limits were not included (see below). In comparison to data from the *World Small Hydropower Development Report (WSHPDR) 2016*, installed capacity has increased by approximately 42 per cent (Figure 4).[43] A feed-in-tariff was the main driver to achieve such a rapid increase in installed capacity. According to the feed-in tariff statistics, the number of new mini-hydropower plants (up to 5 MW) added in 2015, 2016 and 2017 was 206, 180 and 86, respectively, with respective capacities of 47 MW, 58 MW and 33 MW.[46]

Figure 4.
Small hydropower capacities 2013/2016/2019 in the United Kingdom (MW)



Source: SISTEch et al.,[26] BHA,[25, 30] *WSHPDR 2013*,[31] *WSHPDR 2016*[43]

Note: The comparison is between data from *WSHPDR 2013, WSHPDR 2016* and *WSHPDR 2019.*

As of February 2018, based on the plants registered with the British Hydropower Association (BHA), there was an estimated 427 SHP plants in the UK with a total capacity of 268 MW. 65 of these sites were between 1 MW and 9 MW representing more than 74 per cent of the total installed capacity (Table 1). This represents approximately 6.1 per cent of the total hydropower installed capacity and approximately 0.3 per cent of the country's total installed capacity. Almost all of the country's hydropower plants are located in Scotland and Wales.

Table 1.
Small hydropower plants in the United Kingdom registered with the BHA by capacity

	<25 kW	*25-99 kW*	*50-99 kW*	*100-499 kW*	*500-999 kW*	*1-9 MW*
Number of plants	114	31	41	130	46	65
Installed capacity (MW)	1.1	1.1	2.9	31	32.7	198.7

Source: BHA[30]

Due to the costs and concerns about its environmental impact, further large-scale development potential is limited, however, there is scope for exploiting the country's remaining SHP resources in a sustainable way. The good quality most financially viable sites have already been utilized or lie in protected regions of the Scottish Highlands and Snowdonia, Wales. The BHA's 2010 England and Wales Hydropower Resource Assessment Report has identified approximately 1,692 potential sites in England and Wales. The total potential identified by this study is between 146 MW and 248 MW. Between 119 MW and 185 MW are from potential sites located in England and between 59.33 MW and 77.51 MW from potential sites in the north of England.[25,43] A separate study of Scottish SHP potential carried out in 2008 modelled 36,252 separate sites that were deemed practically and technically feasible in Scotland. Of these, 1,019 sites with a potential of 657 MW were deemed financially viable. More than half of these sites were estimated to have a capacity between 100 and 500 kW (Table 2).[26,43] Both studies, however, had lower limits in terms of the potential capacity of sites that were included. For the England and Wales study, a lower limit of 25 kW was set for remote sites and for the Scottish study there were limits of 100 kW for sites in the north of Scotland and 25 kW in the south. This means that a number of pico-hydropower sites were not included, in particular old water mills that could be modernized to provide generate electricity. With some estimates suggesting there could be 20,000 old water mill sites in England alone, there remains significant potential unaccounted for.[43,44]

Table 2.
Potential small hydropower plants in Scotland by capacity (MW)

	<100kW	*100kW-500kW*	*500kW-1MW*	*1MW-5MW*	*5MW-10MW*
Number of sites	6	537	300	170	6
Potential capacity (MW)	0.45	150.4	193.2	276.6	36.2

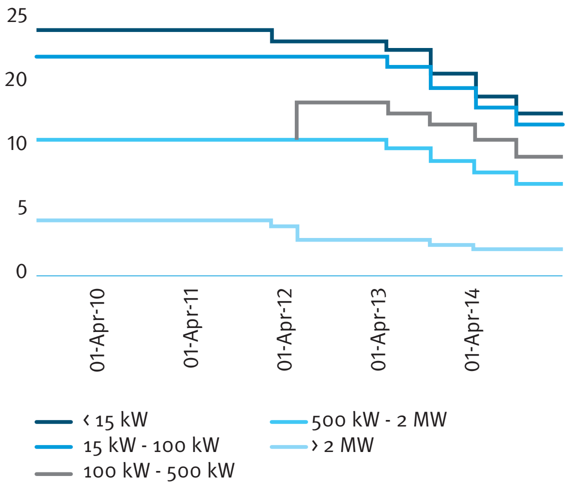
Source: SISTech et al.[26]

Renewable energy policy

The Government has a target of 15 per cent of energy supply from renewable sources by 2020 in order to contribute to the European Union's (EU) overall binding target of 20 per cent of energy consumption from renewable sources by the same year.[17] The Government has indicated that it expects to meet this target with 30 per cent of electricity supplies coming from renewable sources by 2020.[19] Having achieved its own target of 31 per cent by 2013, Scotland has introduced an ambitious renewable energy target of 100 per cent by 2020.[20]

Major polices relating to renewable electricity generation include: the Renewable Obligation (RO), the main support mechanism for large scale renewable projects; Feed-in Tariffs (FITs) for smaller scale renewable projects; and Contracts for Difference (CfD). FITs for renewable energy were announced in October 2008 as part of the Energy Act 2008 and came into effect in April 2010. The tariffs apply to electricity generated from plants of no more than 5 MW utilizing hydropower, solar PV, wind or anaerobic digestion with an eligibility period of 20 years. Micro combined heat and power (CHP) installations of 2 kW or less are also eligible. The FITs cover all energy generated, not just what is fed into the grid. However, electricity that is fed into the grid receives a small additional export tariff of 0.0491 GBP/kWh (0.068 US$/kWh). Since their introduction, the FITs have been slowly reduced at regular intervals with FITs for hydropower being reduced by an average of 25 per cent, while those specifically for plants above 2 MW reduced by almost 50 per cent (Figure 5).[37]

Figure 5.
Feed-in tariffs for hydropower by capacity in the United Kingdom, 2010 – 2016 (pence/kWh)



Source: Ofgem[37]

Note: GBP 1 = 100 pence; GBP 1 = US$ 1.42.

FITs for SHP from 1 January 2018 to 31 March 2018 are given in Table 3. FITs are available only for plants with an installed capacity less than 5 MW. As of December 2017, there were 974 accredited hydropower plants the Central FIT Register with a combined total capacity of 176 MW.[23]

Table 3.
Proposed hydropower feed-in tariffs in the United Kingdom, 1 January 2018 to 31 March 2018

Plant capacity	*Rates*
< 100 kW	GBP 0.0777 (US$ 0.1083)
100 kW - 500 kW	GBP 0.0624 (US$ 0.0870)
500 kW - 2 MW	GBP 0.0624 (US$ 0.0870)
> 2 MW	GBP 0.0454 (US$ 0.0633)

Source: Ofgem [37]

For plants greater than 5 MW, the RO was introduced in England and Wales in 2002 and in Northern Ireland in 2005. In Scotland a different but similar policy, Renewable Obligation (Scotland), was also introduced in 2002. The RO requires electricity suppliers to source an increasing proportion of electricity from renewable sources. In order to demonstrate they have met their obligation, suppliers must obtain Renewable Obligation Certificates (ROCs), which are issued to operators of accredited renewable energy plants. Where suppliers do not present a sufficient number of ROCs to meet their obligation, they must pay an equivalent amount into a buy-out fund.[43]

In the 2013/2014 period, 62.8 million ROCs were issued by the Government, the highest number on record, with each ROC worth GBP 47.72 (US$ 75.83). Suppliers in England, Wales and Scotland were required to present 0.206 ROCs per MWh of electricity supplied while suppliers in Northern Ireland required 0.097 ROCs per MWh. All suppliers met their obligations in this period with 60.8 million ROCs presented for compliance and GBP 42.4 million (US$ 67 million) paid into the buy-out fund. Total supplier obligation was 61.9 million ROCs meaning 98.2 per cent of obligations were complied with via ROCs, the highest proportion since the introduction of the scheme.[33] The RO scheme was phased out in favour of a new scheme, CfD, and closed to all new generating capacity on 31 March 2017, except those generators that are eligible for a grace period.[45]

The CfD scheme was introduced in 2013 and constitutes a contract between a low carbon electricity generator and the state-owned Low Carbon Contracts Company (LCCC). According to the scheme generators are paid the difference between the price for electricity given the cost of investing in a particular low carbon technology and the country's average market price for electricity. According to the Government, the aim of the new scheme is to give generating companies more exposure to market forces in order to encourage greater efficiency, to reduce uncertainty of revenues and to protect consumers from paying higher costs.[34,43]

All hydropower projects must obtain three permissions prior to construction and operation: an environmental licence granted by the relevant regional environmental agency, planning permission granted by the local council or National Park Authorities and accreditation to generate and export electricity provided by Ofgem. To build a new hydropower plant, the developer has to apply to the Environment Agency (Environmental licence) for:

- an abstraction licence - if water is diverted or taken from a river or watercourse;
- an impoundment licence - if it is planned to build a dam or weir to hold back the flow of an inland water, or if it is planned to change an existing weir or structure as part of the scheme;
- a fish pass approval - if it is planned to install or modify fish passes as part of the scheme;
- an environmental permit for a flood risk activity - when the developer builds in, over or next to main rivers (for rivers and watercourses that are not main rivers the developer must apply to the lead local flood authority for consent).[40]

Barriers to small hydropower development

Investment in new SHP plants is limited despite the renewable policies. The FITs have only had a small impact on hydropower, with only 3 per cent of the total cumulative capacity of plants registered for FITs until 2016 coming from hydropower.[21,23] Lowering of the FITs may further deter investors.

In addition, investors and operators must consider environmental issues, including additional features that may impact costs.[27] Developers must not only have the initial financial outlay for the build but also for feasibility studies on the economic viability and environmental impact of a potential site and detailed analysis and expensive hardware to prevent adverse effects on fishing. They also have to counter a range of perceived conflicts with river-based leisure interests and prove that there will be no impacts to the river bed, river banks, flora and fauna, land drainage or the ability to remove flood waters.[28,43]

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4.3 Southern Europe

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Introduction to the region

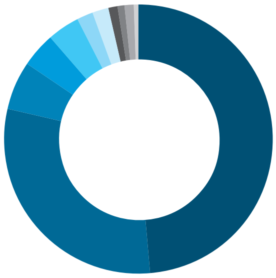
Southern Europe comprises 16 countries and territories. This report covers 11 of them that use small hydropower (SHP) – Albania, Bosnia and Herzegovina, Croatia, Greece, Italy, North Macedonia, Montenegro, Portugal, Serbia, Slovenia and Spain. Six of these countries (Croatia, Greece, Italy, Portugal, Slovenia and Spain) are European Union (EU) member states. Four other countries (Albania, North Macedonia, Montenegro and Serbia) are recognized candidates for EU membership, and Bosnia and Herzegovina is a potential candidate. As a result of the completed or ongoing process of integration with the EU, all countries of the region have their national policies aligned with the EU initiative on renewable energy. An overview of these countries is given in Table 1.

Climate and resource endowments vary from country to country. However, most of them experience the same regional energy-related challenges, namely a dependence on imported fossil fuels, underdeveloped grid infrastructure and climate change, which causes temperature increase and desertification. Due to the region's high dependence on imported energy, it is exposed to geopolitical tensions and commodity price volatility. In order to strengthen their energy security, the countries aim to reduce the share of fossil fuels in electricity production and diversify energy sources, in particular, through the development of domestic renewable energy.

The main renewable energy sources developed in the region are hydropower (23 per cent of the region's total installed capacity), wind power and solar power. With its long history of hydropower exploitation and a total installed capacity of approximately 64.6 GW, hydropower remains critical for Southern Europe. Italy is the third-largest producer of electricity from hydropower in the EU, whereas Croatia and North Macedonia produce more than half of their electricity from hydropower, and Albania depends completely on hydropower.[8] The potential of hydropower remains largely untapped in the region, especially in the Balkan countries. High solar radiation also creates a very good potential for solar energy development, with Italy and Spain being the second and third major solar power contributors in the EU.[8]

* *WSHPDR 2016* updated by ICSHP

Figure 1.
Share of regional installed capacity of small hydropower up to 10 MW by country in Southern Europe (%)



Source: *WSHPDR 2019*[3]

SHP up to 10 MW accounts for 10.6 per cent of the total hydropower installed capacity in the region. The regional leaders in terms of SHP installed capacity are Italy accounting for 49 per cent of the region's total and Spain accounting for 30 per cent (Figure 1).

Table 1.
Overview of countries in Southern Europe

Country	*Total population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Albania	2.9	41	100	2,018	4,525	1,920	4,525
Bosnia and Herzegovina	3.5	52	100	4,352	16,509	2,173	5,843
Croatia	4.2	43	100	4,794	11,403	2,175*	6,556*
Greece	10.8	21	100	19,624	45,806	3,408	3,500
Italy	60.5	30	100	114,161	277,235	22,181	43,785
Montenegro	0.6	34	100	893	3,023	674	1,807
North Macedonia	2.1	42	100	2,057	5,301	675	1,879
Portugal	10.3	35	100	19,519	60,237	6,838	16,909
Serbia	7.0	44	100	7,838	34,441	2,936	9,477
Slovenia	2.1	46	100	3,537	13,029	1,271	4,825
Spain	46.6	20	100	104,121	262,645	20,361*	20,613*
Total	**150. 6**	-	-	**282,914**	**734,154**	**64,612**	**119,719**

Source: *WSHPDR 2019*,[3] WB,[4] WB,[5] HERA,[6] RAE[7]

Note:*Including pumped storage hydropower.

Small hydropower definition

In most countries of Southern Europe the legal definition of SHP is up to 10 MW. The only exceptions are Albania and Greece, which have an upper limit of 15 MW, and Serbia, which uses a 30 MW threshold (Table 2).

Regional small hydropower overview and renewable energy policy

The region's total installed SHP capacity (up to 10 MW) is reported to stand at 6,881 MW, with the individual countries' installed SHP capacities ranging from 25 MW in Montenegro to 3,395 MW in Italy (Table 2). Italy is also the regional leader in terms of SHP potential estimated at over 7 GW. The total potential of SHP up to 10 MW in Southern Europe is estimated to be at least 14 GW, with a significant number of projects awaiting implementation.

When also taking into account the potential of Greece for SHP up to 15 MW, the region's total potential increases to 16 GW, of which approximately 43 per cent has been developed to date (Figure 2). Spain and Slovenia have already used most of their SHP potentials, while less than 10 per cent of it has been tapped in Bosnia and Herzegovina so far. However, it should be noted the exact regional potential is unknown because many countries do not have accurate and comprehensive data.

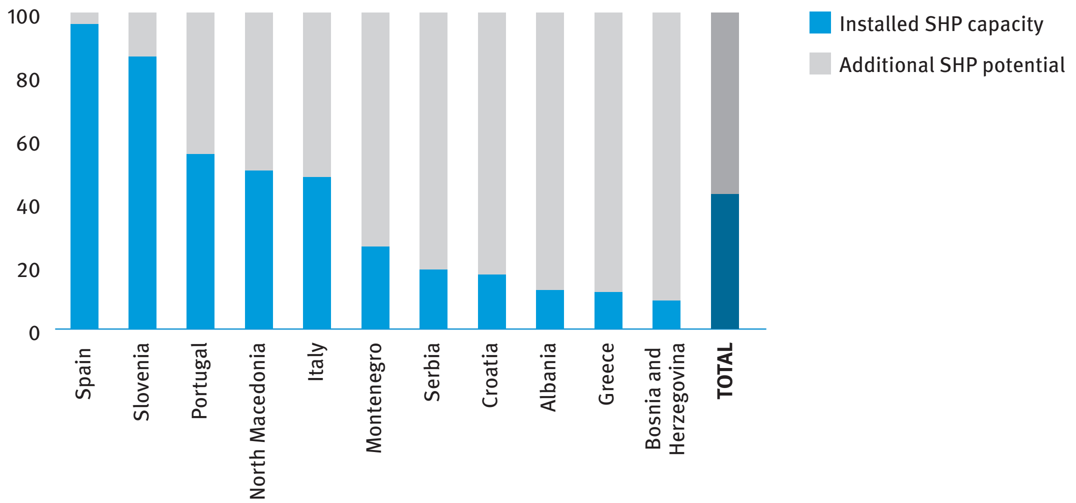
Compared to the *World Small Hydropower Development Report (WSHPDR) 2016*, the region's installed capacity increased by approximately 14 per cent, with the most significant changes in absolute terms reported for Spain and Albania (Figure 3).

Table 2.
Small hydropower capacities in Southern Europe (local and ICSHP definition) (MW)

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed (<10 MW)*	*Potential (<10 MW)*
Albania	up to 15	330.2	N/A	240.2	1,963.0
Bosnia and Herzegovina	up to 10	90.0	1,005.0	90.0	1,005.0
Croatia	up to 10	33.0	192.0	33.0	192.0
Greece	up to 15	232.0	2,000.0	232.0	600.0
Italy	up to 10	3,395.0	7,073.0	3,395.0	7,073.0
Montenegro	up to 10	25.3	97.5	25.3	97.5
North Macedonia	up to 10	130.0	260.0	130.0	260.0
Portugal	up to 10	414.0	750.0	414.0	750.0
Serbia	up to 30	87.6	N/A	87.6	467.2
Slovenia	up to 10	155.0	180.0	155.0	180.0
Spain	up to 10	2,079.0	2,158.0	2,079.0	2,158.0
Total		-	-	**6,881**	**14,746**

Source: *WSHPDR 2019*,[3] Kaldellis et al.[9]

Figure 2.
Utilized small hydropower potential by country in Southern Europe (local SHP definition) (%)



Source: *WSHPDR 2019*[3]

Note: This Figure illustrates data for local SHP definitions. For Albania and Serbia, the data is presented for the SHP definition up to 10 MW due to the absence of data on potential capacity according to the local definitions.

In Southern Europe, SHP, with its significant untapped potential, plays an increasingly important role in the growth of renewable energy, which is one of the main priorities for the countries' energy development in accordance with EU policies. All countries of Southern Europe, as members of the EU or candidates for EU membership, follow EU Directive 2009/28/CE, which sets the target of a 20 per cent share of renewable energy sources in the EU gross final energy consumption to be achieved by 2020.

An overview of SHP in the countries of Southern Europe is outlined below. The information used in this section is extracted from the country profiles, which provide detailed information on SHP capacity and potential, among other energy-related information.

Due to its topography, **Albania** is quite rich in hydropower resources, with an estimated potential for SHP up to 10 MW standing at 1,963 MW. The installed capacity of SHP up to 10 MW is 240.2 MW, indicating that 12 per cent has been developed. For SHP plants up to 15 MW the installed capacity is 330.2 MW. Since the *WSHPDR 2016*, the installed capacity has nearly tripled due to the construction of new plants. The Government has set the development of the energy sector among its priorities, focusing on the development of renewable energy resources and, in particular, hydropower. The country's total hydropower reserves could enable an annual generation of up to 16 TWh.

In **Bosnia and Herzegovina**, there are 74 SHP plants with a total installed capacity of approximately 90 MW. The potential is estimated at 1,005 MW or 3,520 GWh. Compared to the *WSHPDR 2016*, installed capacity has increased by 150 per cent, which is mainly due to access to more accurate data. In 2016, renewable energy accounted for more than 50 per cent of the country's energy mix but less than 36 per cent of electricity generation. According to the National Renewable Energy Action Plan (NREAP), by 2050 the share of renewable energy should reach 52.4 per cent in the country's electricity sector, 56.9 per cent in heating and cooling and 10 per cent in the transportation sector.

Croatia has 31 SHP plants with a total installed capacity of nearly 33 MW. Thus, the installed capacity of Croatia has remained unchanged since the *WSHPDR 2016*. The SHP potential is estimated at 192 MW, indicating that 83 per cent remains untapped. The tariff system introduced in 2014 set the quota of 35 MW for SHP until 2020, and 744 MW of wind power plants connected to the grid. To reach the hydropower target, 11 plants with a combined capacity of 3.9 MW were installed. There are also pending contracts with an installed capacity of roughly 4.2 MW. In addition, a number of large-scale hydropower projects are planned to be developed, including two plants of 300 MW and 138 MW.

The installed capacity of SHP in **Greece** is 232 MW from 115 SHP stations of around 2 MW each. The economic potential for SHP up to 15 MW is estimated to be 2,000 MW, indicating that approximately 11 per cent has been developed. Since the *WSHPDR 2016*, the installed capacity increased by 9 MW. Additionally, approximately 60 projects, reaching a total of 200 MW, have obtained binding connection offers, while more than 300 MW are under approval. The current strategy of reducing fossil fuel dependence has predominantly focused on large-scale installations of wind farms and solar PV panels, while hydropower has seen a lack of political interest.

Italy has 2,745 micro - and mini - hydropower plants with an installed capacity of 769 MW, and 872 SHP plants with a capacity of 2,626 MW. Compared to the *WSHPDR 2016*, installed capacity has increased by 7 per cent. The country's SHP potential for plants up to 10 MW exceeds 7 GW. SHP growth has been driven by comprehensive FITs, which have strongly promoted new SHP plants. However, the cost of this strategy is still being paid by the Government, which has recently started a gradual reduction of FITs for SHP. The National Energy Strategy forecasts the overall hydropower production to reach 50 TWh by 2030 through the revamping of large hydropower plants and the construction of new SHP plants.

With a total installed SHP capacity of 25 MW, **Montenegro** has 16 SHP plants, of which seven are 30 or more years old and nine were built in the last three years. Compared to the *WSHPDR 2016*, installed capacity has increased by 42 per cent. The potential is estimated at 97.5 MW, indicating that 26 per cent has been developed. In 2007, the Government started offering concessions to private investors for SHP construction. As of 2015, 46 new privately-owned SHP plants were approved with an overall capacity of nearly 91 MW. While hydropower is expected to remain the dominant energy source, the country's energy development strategy aims to diversify the energy mix with wind, solar and biomass energy and other renewable energy sources.

North Macedonia has approximately 90.6 MW of SHP, which annually generates 389 GWh. Compared to data from the *WSHPDR 2016*, installed capacity has increased by 43 per cent. Currently, SHP accounts for approximately 15.5 per cent of the total installed hydropower capacity and approximately 4.4 per cent of the country's total installed capacity. However, it is estimated that SHP could potentially meet up to 16 per cent of the country's current electricity demand. The country's total potential capacity is estimated at 260 MW.

The installed capacity of SHP in **Portugal** is 414 MW, indicating a 11 per cent increase compared to the *WSHPDR 2016*. There have not been any comprehensive studies of SHP potential, however, the NREAP is aiming for a total of 750 MW from 250 SHP plants by 2020, indicating that at least this potential exists. A key challenge for the Portuguese energy sector is to reduce energy dependence, a goal which can only be achieved by developing renewable energy sources. By 2030, a further 7,100 MW of installed capacity from renewable sources is expected to be added to the country's energy mix.

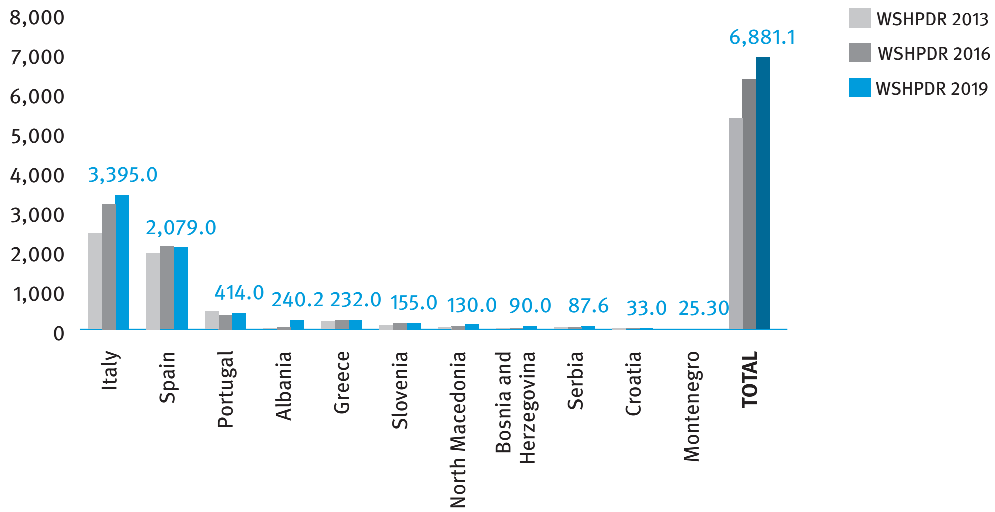
There are 131 SHP plants operating in **Serbia**, which range in capacity from 10.7 kW to 7 MW. Their combined installed capacity is 87.6 MW. Since the *WSHPDR 2016*, installed capacity almost doubled due to the commissioning of new plants. Over 70 of these plants were commissioned after 2016. The potential for SHP development (up to 10 MW) in the country is estimated at approximately 467 MW from a total of 856 sites. Thus, 19 per cent of the potential has been developed to date. The Energy Sector Development Strategy adopted in 2016 encourages investment in renewable energy and sets the goal for the total installed capacity of new renewable energy plants to reach 1,835 MW by 2030.

The installed capacity of SHP plants in **Slovenia** is 155 MW, coming from 424 plants. Compared to the results of the *WSHPDR 2016*, the installed capacity decreased by approximately 1 per cent. The technically and economically feasible potential is estimated to be around 180 MW. However, taking into consideration the environmental, legal and spatial limitations, the exploitable potential should be more limited. From 2015 to 2017, 40 new water permits for SHP plants were issued. The NREAP 2010-2020 set the target to increase the installed capacity of SHP plants with capacity of 1-10 MW by 16 MW. In general, the support for hydropower in Slovenia is mixed, and comprehensive studies are necessary to prepare a Master Plan defining potential sites considering the environmental objectives.

Spain has 1,078 SHP plants with a combined installed capacity of 2,079 MW, whereas the SHP potential is estimated at 2,185 MW. Between the *WSHPDR 2016* and *WSHPDR 2019*, installed capacity decreased by 25 MW. The decrease in installed capacity is due to the crisis the SHP sector of the country is currently undergoing, with a number of plants having been closed. SHP generation is highly dependent on water availability. Thus, in 2017, as a result of low rainfall, electricity generation from SHP plants fell by 33 per cent compared to 2016.

In order to promote the development of renewable energy, all countries of the region have implemented economic incentives, which have also driven the growth of SHP. Thus, suppliers of electricity from renewable sources have received a range of benefits, which include **feed-in tariffs (FITs)** and premiums**,** priority connection to the grid, guaranteed purchase of electricity, preferential access to the network and subsidies. Greece recently abandoned the FIT system in favour of a new feed-in premium (FIP) scheme. Since 2012, new plants in Portugal do not receive support in the form of FITs. In 2012 Spain also suspended FIT pre-allocation and removed economic incentives for new power generation.

Figure 3.
Change in installed capacity of small hydropower from *WSHPDR 2013* to *2019* by country in Southern Europe (MW)



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

Note: *WSHPDR* stands for *World Small Hydropower Development Report.* For all countries, data is for SHP up to 10 MW.

Barriers to small hydropower development

Although Southern Europe has a significant SHP potential, its further development is hampered by a number of factors. One of the most common barriers is the long and complicated authorization and licensing process. Other institutional and regulatory barriers include corruption, disagreement between local and national regulations and institutions. Some countries also have issues related to water management, and finding the required initial capital investment can be problematic.

The main obstacles to SHP development in **Albania** are related, but not limited to the lack of financing. Power losses reaching above 30 per cent also entail a significant problem.

In **Bosnia and Herzegovina**, the most important barriers to SHP development include the discrepancy between regulations at the entity level and the local community or municipality levels, the changing renewable energy policies as well as favouritism and corruption that potential investors might face at any stage of project development.

In **Croatia**, the environmental rules and procedures that SHP projects need to follow are not defined clearly, and there are several state agencies responsible for obtaining permits for development and construction of SHP plants, which complicates the process. There is also no reliable plan with the exact locations of potential sites. As the renewables target for Croatia has already been reached, there is less political support for new SHP projects, while funds for SHP projects are limited, due to high upfront investment and long payback period.

Some of the major drawbacks decelerating SHP development in **Greece** are the administrative bureaucracy, which leads to a lengthy process of obtaining licences, and the absence of an integrated national water management plan. Furthermore, SHP development is mostly realized by small private companies, which frequently come across multiple challenges, such as limited budgets, and a lack of expertise and knowledge of the sector.

In **Italy**, the recent cut in FITs for SHP has extended payback periods, which is expected to discourage investors. The authorization process takes 2-3 years on average, with permissions being granted by different departments. In addition, the environmental regulations aiming to preserve river networks coupled with social movements against SHP limit hydropower development.

Montenegro lacks general and strategic water plans. SHP potential is the highest in the regions that have weak distribution networks and also low electricity demand.

Some of the most critical issues concerning the development of SHP in **North Macedonia** include the lack of accurate hydrological data, the lack of or an unstable distribution network in the areas of high SHP potential, high investment costs of grid connection and the absence of a single authority for all related procedures in order to reduce the time needed to realize the projects.

Portugal is in a slow stage of development of its SHP sector with only a few power plants being developed in the last decade. The major barriers include a lengthy, costly, and unpredictable licensing procedure, legal constraints, particularly in regard to more stringent environmental requirements, and inadequate support mechanisms.

In **Serbia**, current legislation and policies aim to promote more intensive development of SHP. However, complicated permit issuing procedures, high costs of preliminary and main project drafting, limited funds for investing in projects, low awareness of the advantages of SHP both among professionals and the public as well as insufficient knowledge of technologies, economic and ecological indicators are limiting further SHP development.

In **Slovenia**, the human and financial resources for SHP development are limited, which translates into inadequate data management, lack of supervision and a stronger position of water management objectives in spatial planning and land use, inadequate maintenance of the water infrastructure and watercourses and also in unclear and non-straightforward decision making. In general, there is a mistrust for new SHP development, since many existing SHP plants do not follow environmental requirements.

In **Spain**, the new economic regime of electricity generation makes SHP generation uneconomic. The administrative process for obtaining a licence and authorization is complex, while renewing the water concession periods of the current hydropower plants can be difficult as well. In addition, there is limited knowledge regarding the actual potential of some sites.

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4.3.1

Albania

Arian Hoxha, Albanian Distribution System Operator (OSHEE); and International Center on Small Hydro Power (ICSHP)

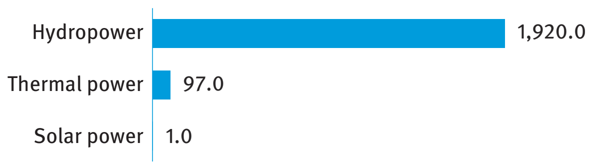
Key facts

Population	2,873,453[1]
Area	28,748 km[2]
Climate	Albania is situated in a transition zone between the Mediterranean climate and the moderate continental climate. On the coastal plan, winters are cool, cloudy and wet and summers are hot, clear and dry. In the mountainous interior part of the country, rainfall in summer is more common and winters are cooler. The average annual temperature is 15 °C, the minimum average temperature 1.6 °C and the maximum average temperature 20.9 °C.[2]
Topography	Albania is made up of mostly mountainous terrain, with small plains along the coast and river valleys. The highest peak is Mount Korab at 2,751 metres above sea level, situated in the east, at the border with North Macedonia.[2]
Rain pattern	Average annual rainfall is 1,430 mm with 1,000 mm on the coast and over 2,500 mm in the mountains. Approximately 70 per cent of rainfall occurs from November to March.[2]
Hydrology	Albania has 11 major rivers with their 150 tributaries. The longest river is the Seman, which is 281 km long and divides into the Devoll and Osum. The Vjosa, 272 km long and originating from Mount Smolikas, is the most torrential river in Albania.[3] The average altitude of the hydrographical territory is approximately 700 metres above sea level. The total average flow of the rivers is approximately 1,245 m^3/sec.[4]

Electricity sector overview

The main power producer is the Albanian Power Corporation S.A (KESH). It is completely state-owned.[5] The total installed capacity of power plants connected to the grid in the first quarter of 2017 was 2,018 MW, with the installed capacity of hydropower at 1,920 MW (Figure 1). The thermal power plant (TPP) in Vlora has an installed capacity of 97 MW.[6] However, the Vlora TPP has not been used due to issues with its cooling system and high generation costs.7 In addition to the hydropower plants and one thermal plant, there was one solar power plant with a capacity of 1 MW operated by Ujesjelles Kanalizime Korçë. Of the country's total installed capacity, KESH operated 1,447 MW.[6]

Figure 1.
Installed electricity capacity by source in Albania (MW)

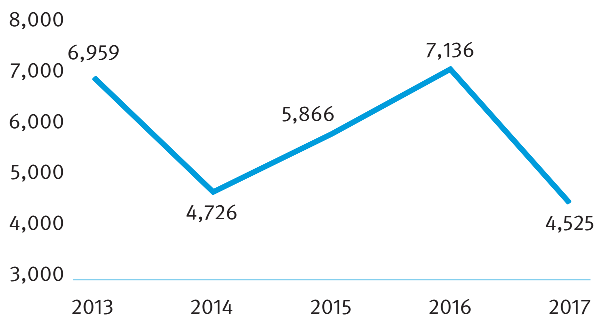


Source: ERE[6]

* *WSHPDR 2016* updated by ICSHP

The total generated electricity in 2017 was 4,525 GWh, all of which was from hydropower. Compared to 2016, electricity generation in Albania decreased by 37 per cent due to lower hydropower generation. As a result, electricity imports had to increase significantly – from 1,827 GWh in 2016 to 3,403 GWh in 2017.[8]

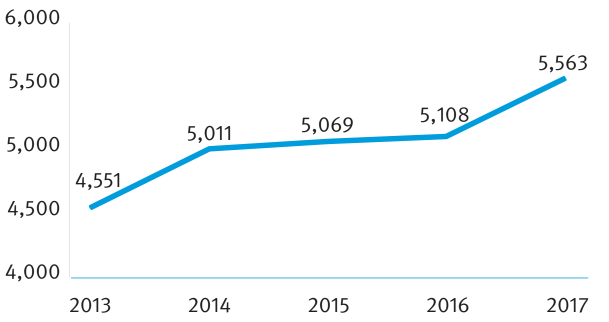
Figure 2.
Generation of electricity in Albania, 2013-2017 (GWh)



Source: ERE[9]

It should be noted that electricity generation in Albania demonstrates a significant difference between the highest and the lowest generation volumes due to the changing water flows (Figure 2).[9] This poses a significant risk for the country's power security and stability. At the same time, electricity consumption in the country has been steadily increasing, with 5,563 GWh reached in 2017 (Figure 3).[9]

Figure 3.
Net electricity consumption in Albania, 2013-2017 (GWh)



Source: ERE[9]

The thermal power plant at Vlora was meant to start operating in 2011, but due to technical problems it has remained idle. However, there are plans to revive the plant by feeding it with gas from the planned Trans Adriatic Pipeline (TAP).[7] A feasibility study for the construction of a pipeline to link the cities of Fier and Vlora was carried out and as of October 2018 was under the consideration of the Government of Albania.[10]

Table 1.
Electricity tariffs in Albania for 1 April – 31 December 2017

Type		*Approved tariff (ALL (US$) per kWh)*
Production		1.45 (0.013)
Transmission		0.65 (0.006)
Users of distribution grid at 35 kV		1.50 (0.014)
Users of distribution grid at 20 kV		3.90 (0.036)
Average tariff of distribution system		4.79 (0.044)
HPP up to 15 MW		7.45 (0.069)
Distribution retail prices	*Off peak*	*Peak*
Consumers at 35 kV	9.50 (0.088)	10.93 (0.100)
Consumers at 20 kV	11.00 (0.100)	12.65 (0.120)
Consumers at 10/6 kV	11.00 (0.100)	12.65 (0.120)
Consumers at 0.4 kV	14.00 (0.130)	16.10 (0.150)
Consumers connected in medium voltage with metering in low voltage	12.40 (0.110)	14.30 (0.130)
Households	9.50 (0.088)	9.50 (0.088)

Source: ERE[12]

The transmission system of Albania comprises 400 kV, 220 kV, 110 kV lines and interconnected substations that serve transmission and international interconnectivity. The latter includes 400 kV lines from Albania to Kosovo, from Albania to Greece, from Albania to Montenegro and from Albania to North Macedonia, 220 kV lines from Albania to Kosovo and from Albania to Montenegro, and 150 kV lines from Albania to Greece. The public entity responsible is the Transmission System Operator.[11]

The Distribution System Operator (OSHEE) is a fully public-owned company. Recent initiatives and reforms have achieved a positive impact on the reduction of electricity losses (both technical and non-technical) and increased the collection rate of unpaid bills. The level of electricity losses was reduced from 42 per cent of the total electricity supply in 2013 to 25 per cent in 2017. Approximately 67 per cent of losses in 2017 were classified as technical losses in distribution.[9] The annual collection improved from ALL 49 billion (US$450 million) in 2014 to ALL 59 billion (US$550 million) in 2016.[6]

There have been a number of changes in the sector, which relate to an overall reform process across all areas including legislative and strategic aspects. The country's generating capacity still remains insufficient for meeting its demand. However, overall production has increased.[13]

Until 2015, the electricity market was based on the Transitory Market Model established by the Government Decree No. 539, dated 12 August 2004.[14] The decree defined the actors, roles and responsibilities for addressing all related issues and challenges and also ensuring cooperation in terms of legislation compatibility with the European Union directives. On 30 April 2015, the Albanian Parliament adopted the new Law on Energy Sector, compliant with the Third Energy Package. The law has fully transposed Directive 2009/72/EC. It includes:

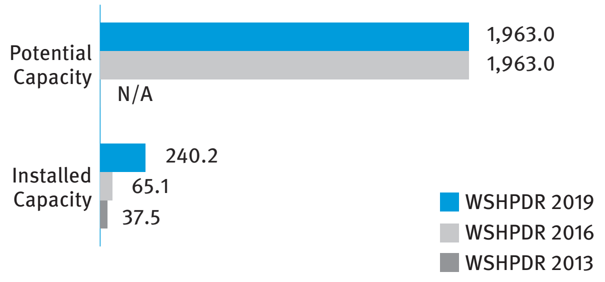
- Liberalization, organization, participation and functioning of a competitive electricity market;
- Authorizations and licensing procedures in the electricity sector;
- Consumer protection, security of supply and competitive structures in place within the sector;
- Integration of the Albanian electricity market into the regional and European electricity market.[13]

Decision No. 519 of 13 July 2016 approved the electric power market model of Albania, which aims to assure a steady structure and create conditions for the further regional integration between Albania and its neighbouring countries.[15]

Small hydropower sector overview

The definition of small hydropower (SHP) used in Albania is up to 15 MW.[16] As of the first quarter of 2017, the installed capacity of SHP plants up to 15 MW was 330.18 MW and up to 10 MW 240.19 MW.[6] The potential up to 10 MW is estimated to be 1,963 MW, indicating that 12 per cent has been developed.[13] Between the *World Small Hydropower Development Report* (*WSHPDR*) *2016* and *WSHPDR 2019*, installed capacity has nearly tripled due to the construction of new plants, while potential remained unchanged (Figure 4).

Figure 4.
Small hydropower capacities 2013/2016/2019 in Albania (MW)



Source: ERE,[6] *WSHPDR 2016*,[13] *WSHPDR 2013*[17]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

Note: Data is for plants up to 10 MW.

Due to its topography, Albania has numerous rivers, with more than 150 rivers and torrents forming eight main big rivers. They have a south-east to north-west flow, mainly oriented towards the Adriatic coast. The most important rivers are the Drin (340 m^3/sec), Vjosa (210 m^3/sec), Seman (101 m^3/sec), Mat (74 m^3/sec), and Shkumbin (60 m^3/sec) rivers. Although they have small flows, their considerable inclination makes them important for hydropower development. Consequently, Albania is seen as a country rich in water reserves and its hydropower potential can play an important role in the development of the country.[13]

Considering the current power supply situation as well as the potential demand for power, the Government has set the development of the energy sector among its priorities, focusing on the development of renewable energy resources and, in particular, hydropower plants. There is a large hydropower potential and currently only 43 per cent of it is being used. The total hydropower reserves could enable the installation of a 4,500 MW power network and its annual electricity power production could reach up to 16 TWh. Based on studies carried out by international consultants, the main potential areas for installation of hydropower plants are the Drin River, the Osum River, the Vjosa River and the Erzen River.[4] As of December 2017, 183 concession contracts were signed for the construction of 524 SHP plants up to 15 MW.[11]

Renewable energy policy

Under Directive 2009/28/EC, Albania has committed to a binding 38 per cent target of energy from renewable sources in gross final energy consumption in 2020, compared with 31.2 per cent in 2009. The network operators have to increase transparency regarding connection and access to the grids.[13]

In 2017, the Government adopted the Law on the Promotion of the Use of Energy from Renewable Sources, according to which small installations up to 2 MW (3 MW for wind) are entitled to claim a feed-in tariff (FIT). Renewable power producers with a power purchase agreement (PPA) that were commissioned before 2020 will receive fixed FITs and the right to switch to the new support scheme for the rest of the contract period. Installations above 2 MW will receive support under contracts for difference (CfD), which are based on the difference between an administratively prefixed price and a measure of the market price for electricity and are provided for a period of 15 years.[18]

Established by the Power Sector Law (Law No.9072), the Energy Regulator Authority (ERE) is responsible for granting licences to power producers with separate licences for generation, transmission and distribution of electricity. Under its Rules of Practice and Procedure (Decision No.21 dated March 18, 2009), the ERE guarantees equal treatment in issuing licences and resolving disputes between parties. More specifically, under the Rules and Procedures on Certification of Electricity from renewable energy sources, the ERE has outlined the procedures for generators to apply for green certificates and approval of project implementation.[13]

The criteria for authorization of new electricity generating capacity without concessions are duly transposed by the Power Sector Law, whereas tendering for new capacity is not treated in the Power Sector Law but indirectly governed by the Law on Concessions. This has helped increase the participation of independent power producers (IPP) in the development of SHP installations or the rehabilitation of existing mini-grid systems, such as the successfully implemented Arras SHP plant.[13,19]

Barriers to small hydropower development

While SHP installed capacity has risen considerably in recent years, the progress of SHP development in Albania is slower than expected. The main obstacles to SHP development are related, but not limited to the lack of financing.[13]

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4.3.2

Bosnia and Herzegovina

Nihad Harbas, nLogic Advisory Sarajevo

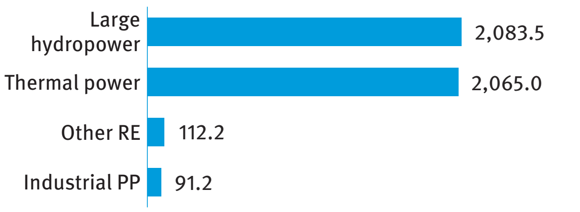
Key facts

Population	3,511,372 [1]
Area	51,209 km^2 [1]
Climate	There are three climate zones in Bosnia and Herzegovina – a moderate continental in the north, a mountainous in the central part of the country and a Mediterranean in the south-west. In the north, the average air temperature varies between -1 °C and -2 °C in January and between 18 °C and 20 °C in July. At altitudes above 1,000 metres temperatures are between -4 °C and -7 °C in January and between 9 °C and 14 °C in July. On the Adriatic coast and in Low Herzegovina, temperatures vary from 3 °C to 9 °C in January and from 22 °C to 25 °C in July. The minimum recorded temperature is -41.8 °C, whereas the maximum is 42.2 °C.[2]
Topography	The country is mainly covered by hills and mountains, with altitudes ranging from 0 metres at the seacoast to 2,387 metres at the highest peak, Maglić. The average altitude is 500 metres above sea level. Of the total land area 42 per cent is mountains, 29 per cent karst region, 24 per cent hills and 5 per cent lowlands. Forests cover approximately 25,000 km^2, or 49 per cent of the total area.[3]
Rain pattern	Annual precipitation varies from 800 mm in the north up to 2,000 mm in the central and south-eastern mountainous regions. In the Danube River basin area, the major part of the annual precipitation occurs in the warmer part of the year, reaching its maximum in June. In the central and southern parts of the country, under the influence of the Adriatic Sea, the maximum precipitation happens in late autumn and early winter, mostly in November and December.[2]
Hydrology	The rivers and lakes of Bosnia and Herzegovina are part of the hydrographical basin of the Black Sea and the Adriatic Sea. There are seven river basins – Una, Vrbas, Drina, Sava, Neretva, Trebišnjica, and Cetina. The Sava is the most prominent river that flows into the Black Sea and runs 345 km in Bosnia and Herzegovina, along the northern border with Croatia. All major rivers in the country flow into the Sava River, which is the largest tributary of the Danube. The only river that flows into the Adriatic Sea is the Neretva in Herzegovina. There are also numerous river lakes and mountain lakes, as well as geothermal groundwater resources.[3,4]

Electricity sector overview

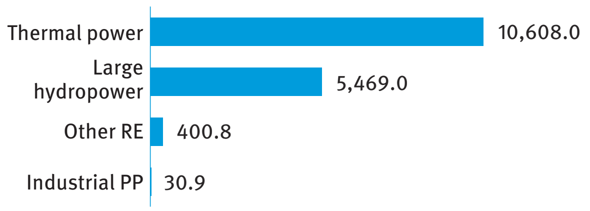
In 2016, the total installed capacity in Bosnia and Herzegovina was 4,352 MW, with 2,083.5 MW (47.8 per cent) from large hydropower, 2,065 MW (47.5 per cent) from thermal power plants, 112.15 MW (2.6 per cent) from small hydropower, wind and solar power plants combined and 91.23 MW (2.1 per cent) from industrial power plants (Figure 1).[5]

Figure 1.
Installed electricity capacity by source in Bosnia and Herzegovina (MW)



Source: SERC[5]

Figure 2.
Annual electricity generation by source in Bosnia and Herzegovina (GWh)



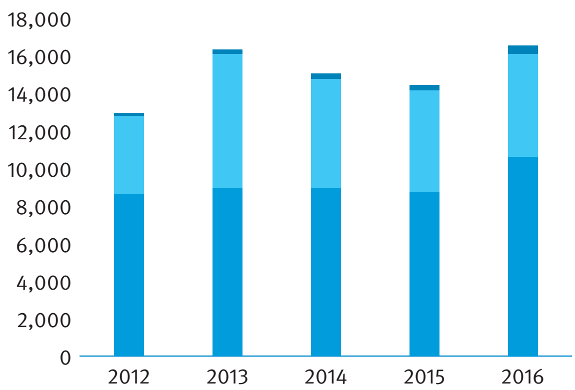
Source: SERC[5]

In 2016, total electricity generation of Bosnia and Herzegovina was 16,509 GWh, marking the highest ever generation registered in the country. The increase of 1,101 GWh, or 14.6 per cent, in comparison with the previous year was a direct consequence of the construction and commencement of operation of the thermal power plant Stanari with a projected annual generation of more than 2,000 GWh.[5] Approximately

64 per cent came from thermal power plants, 33 per cent from hydropower and less than 2.6 per cent from other renewable sources and industrial power plants combined (Figure 2).[5]

Large hydropower plants produced 5,469 GWh, or 0.8 per cent more than in 2015. Generation by thermal power plants reached a record of 10,608 GWh, which was 1,896 GWh, or 21.8 per cent more than in 2015. Generation (small hydropower, solar and wind power plants) of 400.8 GWh from small-scale renewable energy sources, also indicated a significant increase of 62.3 per cent compared to the previous year. The dominant share in this category was held by the small hydropower plants (374.27 GWh, or 93.4 per cent), the solar power plants produced 26.5 GWh (6.6 per cent), while the wind power plants produced only 0.03 GWh (0.007 per cent). Industrial power plants produced 30.9 GWh.[5] A breakdown of generation over the years 2012-2016 is given in Figure 3.

Figure 3.
Annual electricity generation in Bosnia and Herzegovina in 2012-2016 (GWh)



Source: SERC[5]

Total electricity consumption in 2016 amounted to 12,865 GWh, indicating a slowdown in the upward trend from 3.2 per cent observed in the previous year to 2.1 per cent. Nonetheless, with this the total electricity consumption reached a historic maximum.[5]

Despite the significant potential and the commercial activities of the industry, the country's electricity market remains structurally underdeveloped. As established by the 1995 Dayton Agreement, Bosnia and Herzegovina has the national government and second-tier governments of the Federation of Bosnia and Herzegovina (FBiH) and the Republika Srpska (RS). Following this unique political structure, the country has three energy regulatory bodies — one at the national level and two entity-level regulators. This complicates the work of the regulators and the operation of the sector, making it less efficient.[6]

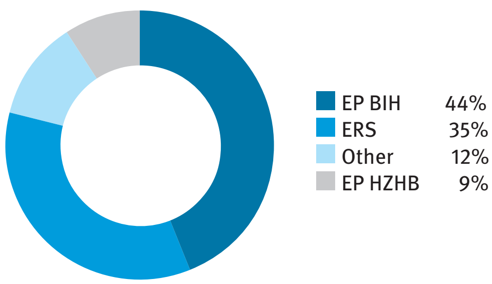
The Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina (MOFTER) is the primary regulator of the energy sector at the national level. The State Electricity Regulatory Commission (SERC) is in charge of the regulatory implementation with regards to the electricity transmission, transmission system operation and international trade. At the entity level, the energy sector is regulated by the Ministry of Energy, Mining and Industry of the Federation of Bosnia and Herzegovina (FMEMI) and the Ministry of Industry, Energy and Mining of the Republika Srpska (MIEMRS). The Federation of Bosnia and Herzegovina Electricity Regulatory Commission (FERK) and the Republika Srpska Energy Regulatory Commission (RERS) implement regulation of the electricity generation, distribution and supply within each entity, respectively.[6]

The participants of the electricity market include:

- Independent System Operator in Bosnia and Herzegovina (ISO BiH), which started operating in July 2005;
- Transmission company Elektroprenos Bosne i Hercegovine, which started operating in February 2006;
- Vertically integrated utility Elektroprivreda BIH Sarajevo (EP BiH);
- Vertically integrated utility Elektroprivreda HZHB Mostar (EP HZHB);
- Vertically integrated utility Elektroprivreda RS Trebinje (ERS);
- Komunalno Brčko carrying out distribution and supply in the Brčko District;
- Traders;
- Eligible customers.

In 2016, EP BiH contributed approximately 44 per cent of the overall electricity generation in the country, ERS contributed 35 per cent, EP HZHB 9 per cent and other entities 12 per cent (Figure 4).[5]

Figure 4.
Electricity generation in Bosnia and Herzegovina by generation company (%)



Source: SERC[5]

The transmission network in Bosnia and Herzegovina consists of 110 kV (cable), 110 kV, 220 kV and 400 kV facilities. The total number of overhead lines is 306 with a total length of 6,372 km and a total of 37 interconnections.[7] The total number of substations is 155 + 4 (MV), with a combined installed capacity of 13,022 MVA + 169.0 MVA (MV) and the total number of transformers is 276 + 31 (MV) with a combined installed capacity of 13,022 MVA + 169.0 MVA (MV).[7]

The total price for electricity is calculated based on the cost of electricity production, the cost of purchase of electricity from renewable energy sources, the supplier's service cost, and the fee for renewable energy sources. The Regulation of the Government of the Federation of Bosnia and Herzegovina on Renewable Energy Sources and Cogeneration from 2014 introduced a fee for renewable energy, with each supplier being obliged to submit an invoice to the customer highlighting the amount of total compensation for the promotion of renewable energy sources.[6]

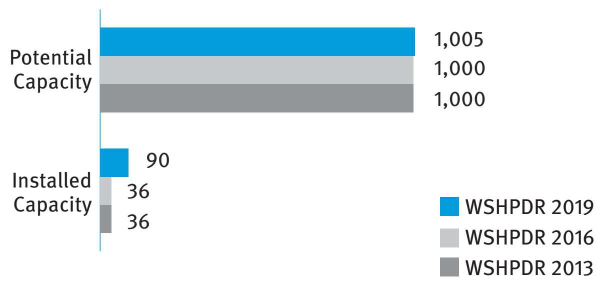
Average tariffs in 2017 were EUR 0.086 (US$ 0.106) per kWh for household consumers and EUR 0.059 (US$ 0.072) per kWh for non-household consumers.[8] For electricity generation from renewable sources (and for efficient cogeneration) suppliers receive a number of benefits including priority connection to the grid, preferential access to the network (dispatch), guaranteed purchase of electricity, a guaranteed feed-in tariff and the right to a premium for the consumption of electricity for their own use or sold on the market.[9]

Small hydropower sector overview

Small hydropower in Bosnia and Herzegovina is defined as hydropower plants with an installed capacity of less than 10 MW.[10]

By the end of 2016, there were 74 small hydropower plants with a total installed capacity of approximately 90 MW, mostly under the feed-in tariff (FIT) incentive scheme, in Bosnia and Herzegovina.[12,13] Small hydropower potential is estimated at 1,005 MW or 3,520 GWh, including 2,090 GWh in the Federation of Bosnia and Herzegovina and 1,430 GWh in the Republika Srpska.[14] Compared to the *World Small Hydropower Development Report (WSHPDR) 2016*, potential capacity has increased only marginally, whereas installed capacity has increased by 150 per cent (Figure 5). Such a significant increase in installed capacity is mainly due to access to more accurate data.

Figure 5.
Small hydropower capacities 2013/2016/2019 in Bosnia and Herzegovina (MW)



Source: *WSHPDR 2016*,[6] OIEiEK,[12] RERS,[13] Gvero, P.,[14] *WSHPDR 2013*[22]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

Electricity from renewable sources, including the small hydropower plants, is mainly purchased by the domestic energy companies. They buy electricity at much lower prices than is guaranteed, with the difference amounting to almost half the price in the Federation of Bosnia and Herzegovina and to approximately two-thirds in the Republika Srpska. This difference is funded by the Fund for Compensation for Renewable Sources, which is sourced from electricity consumers.[6] The fee is charged with each electricity bill and, depending on the energy company, is KM 0.0020 (US$ 0.0013) per kWh without VAT in Federation Bosnia and Herzegovina, and KM 0.0044 (US$ 0.0028) per kWh in the Republika Srpska.[16,17]

Besides the higher electricity prices, investment in small hydropower plants in the Republika Srpska is also more cost-effective due to the purchase guarantees lasting 15 years, as opposed to only 12 years in the Federation of Bosnia and Herzegovina. However, prices can be adjusted even during the period when electricity producers have the right to incentives, which can be detrimental to producers. Concessions are issued for a period of 30 years with the possibility of extension. If not extended, the small hydropower plants are returned to state ownership.[6] The guaranteed price for energy produced by small hydropower is approximately EUR 0.07 (US$0.09) per kWh.[10]

Renewable energy policy

In 2012, in line with the Energy Community Treaty, the Energy Community Ministerial Council adopted an implementation plan for the European Union Directive 2009/28/EC. The legally binding target for Bosnia and Herzegovina is 40 per cent of the renewable energy sources in the country's final energy consumption by 2020. Whereas there is no national law on the renewable energy in Bosnia and Herzegovina, to achieve this goal and promote renewable energy both the Federation of Bosnia and Herzegovina and the Republika Srpska in 2013 adopted entity-level Laws on the Use of Renewable Energy Sources and Efficient Cogeneration.[6,15] On the basis of the adopted laws, both entities also developed and adopted relevant by-laws.

As required by the Energy Community Treaty, the National Renewable Energy Action Plan (NREAP) was adopted at the state level in March 2016. The Plan established the following sectoral targets for the share of renewable energy in the country in 2050 – 52.4 per cent for the electricity sector, 56.9 per cent for the sector of heating and cooling, and 10 per cent for the transport sector. The action plans for the Federation of Bosnia and Herzegovina, the Republika Srpska and the Brčko District to achieve these national targets are also outlined in the document.[19]

The renewable energy sector in each entity is further regulated by other local laws and policies, such as the Energy Development Strategy of Republika Srpska for the period until 2030 (2012). In the Brčko District some aspects of the policy on renewable energy sources are defined in the Law on Electricity (2004) and the Action Plan for Energy Sustainable Development (2015).[19]

At the beginning of 2016, the project "Promoting Renewable Energy in BiH" was launched by the German development agency GIZ, with the goal to create preconditions for augmenting the use of renewable energy in the country.

The project will last until the end of 2019, and involve the respective national and entity ministries and regulators and operators for renewable energy as the key partners. The project provides technical assistance in the field of general improvement of the framework conditions for heat and electricity generation using renewable energy sources, focusing on the use of bioenergy and improvement of technologies for small hydropower plants (up to 10 MW).[21]

Barriers to small hydropower development

Hydropower potential, especially small hydropower potential, has not been sufficiently exploited in Bosnia and Herzegovina. The most important barriers to small hydropower development include:

- The discrepancy between regulations at the entity level and the local community or municipality levels, which usually complicates the process of obtaining necessary permits, which may take anywhere between 18 and 36 months.
- The malleability of policy for renewable energy, meaning that the law can change during the construction phase of projects with potentially negative consequences for owners and/or investors.
- Favouritism and corruption, which potential investors might face at any stage of the construction of small hydropower plants, from the application for the concession and obtaining permits to the approval of a connection to the electricity grid.
- Although the electricity market has been legally entirely open since the beginning of 2015, in general, the existing model for transmission has never been truly unbundled and independent. The electricity market would benefit from being opened up in real terms, including between the entities. This would require a coordinated process for further liberalization of the supply chains and full recovery of costs, together with the creation of a system for the protection of socially vulnerable customers such as pensioners.[6,18,20]

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4.3.3

Croatia

Danilo Fras, Fras Beteiligung und Beratung GmbH; Manuel Mahler-Hutter, Energy Eastern Europe Hydro Power GmbH

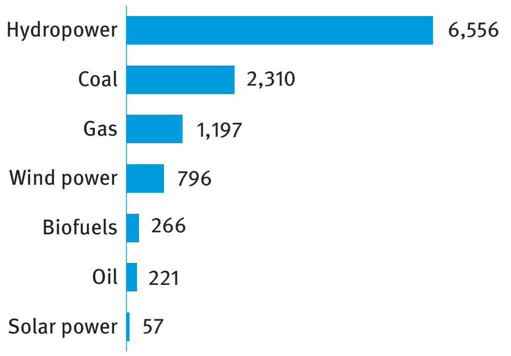
Key facts

Population	4,174,350 [1]
Area	56,594 km^2 [2]
Climate	The climate of Croatia is determined by its 45° position in the northern temperate latitude. It is strongly influenced by the Adriatic Sea and the Mediterranean Sea. Due to its geographic location, the climate in Croatia is moderate, without extreme temperatures. The coastline is characterized by frequent strong winds, the colder "Bura" as well as the warmer "Jugo". The average annual air temperature in Croatia in 2017 was above the multi-annual average (1961 – 1990), reaching 26 °C in summer and roughly 8 °C in winter. The average annual air temperature anomalies were between 0.6 °C and 2.1 °C.[3]
Topography	Croatia's topography includes flat plains along the Hungarian border (Pannonia), low mountains and highlands near the Adriatic coast. There are three distinctive topographical areas – the Pannonian plains in the east and northwest, hills and mountains landscape in the centre, and the Adriatic coast. The highest peak of the Dinar mountains in Croatia is Mount Dinara at 1,831 metres, located on the border between Croatia and Bosnia and Herzegovina.[2]
Rain pattern	Croatia's precipitation regime is as diverse as the country's aforementioned climate and topographic zones. The Pannonian plains are dominated by the continental climate with Mediterranean influence, resulting in the average rainfall of 1,000-1,500 mm per year. The coastal area is characterized by warm and dry summers and wet and stormy, although mild, winters. The average rainfall in coastal area is around 700-800 mm per year. The average precipitation in Croatia between 1901 and 2015 was 1,085 mm. [3]
Hydrology	Within the Danube Basin, where 62 per cent of the Croatian mainland is located, the Sava and Drave rivers are of big importance. These rivers are navigable and cross through multiple countries. The Sava River flows through the Croatian capital Zagreb and along the Bosnian border until it reaches Danube in the Serbian capital, Belgrade. Hydrologically, Croatia can be divided into three units – the North Pannonian basin, with the Drava and the Danube basin, the Sava basin, partly covering the Dinaric karst, with the tributaries Kupa, Bosut and Una, and the Adriatic river basin in the south-western and south area along the coast. The Krka and Cetina rivers in the coastal part of the country flow to the Adriatic Sea and are of special interest as they run at high elevations. [4,5]

Electricity sector overview

In 2016, the total consumption of electricity was 17,674 GWh, out of which 36 per cent were imported. Although technically considered to be imported, around 2,715 GWh were generated in the Slovenian nuclear power plant Krško, 50 per cent of which is owned by Croatia's HEP (Hrvatska elektroprivreda d.d.). This reduces the consumption not covered by the domestic production facilities to roughly 20 per cent. The 2016 domestic production of 11,403 GWh was mainly from hydropower, accounting for (including pumped storage) 55 per cent of the total generation. Fossil generation was around 32 per cent, while wind increased its share to more than 9 per cent from 2013. Croatia is fully electrified, the entire population has access to electricity. Figure 1 details 2016 electricity generation by source.[6]

Figure 1.
Annual electricity generation by source in Croatia (GWh)

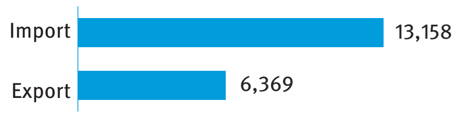


Source: HERA[6]

National Energy Strategy was adopted by the Croatian Parliament in 2009 and has three basic objectives:
- Energy Security;
- Competitiveness of the Energy Sector;
- Sustainable development.[7]

The national target for the renewable energy for the year 2020 was set at 20 per cent of gross consumption, and has been already achieved. In 2016, the renewable energy accounted for 28.3 per cent of the gross consumption. However, due to the revision of data for biomass consumption in residential sector, the updated data for Croatia indicate that the consumption of energy from renewable sources has been above its 2020 target since 2004. The baseline in 2005 was 12.6 per cent. Net imports in 2016 came mainly from Bosnia and Herzegovina (27 per cent), Hungary (31 per cent) and Serbia (14 per cent). Net imports from Slovenia, taking into account the share of the nuclear plant Krško at 2,715 GWh, accounted for 19 per cent (2016 est.).[6] Figure 2 shows the electricity exports and imports in 2015.

Figure 2.
Electricity supply in Croatia (GWh)



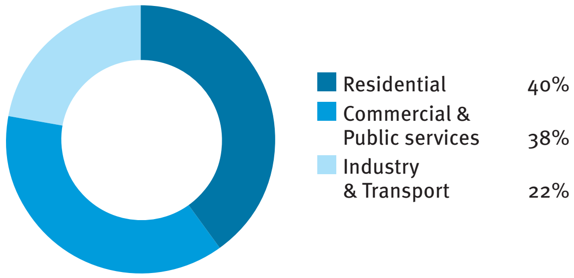
Source: IEA[7]

Although formally open and liberalized, the electricity sector remains dominated by the state-owned companies, especially in the generation department. Privately-owned generators exist, but the majority of the generation facilities belong to the state-owned companies. Almost 85 per cent of the generation is accomplished by HEP group and mostly encompasses large hydropower and thermal energy. As Croatia has been a member state of the European Union (EU) since July 2013, the national electricity market is fully aligned with the EU directives.[8] Croatia has adopted the ITO model of market unbundling, with the Croatian TSO separating from Hrvatska Elektroprivreda, which owns the entire Croatian transmission network.

The most important authorities in the energy sector are the following:
- The Government of Croatia, in charge of introducing policies and strategy;
- The Ministry of Environmental Protection and Energy, in charge of developing Croatian energy policies;
- The Croatian Energy Regulatory Agency (HERA), the independent public institution in charge of regulating energy activities;
- The Croatian Hydrocarbons Agency.[8]

The total installed capacity on Croatian territory by the end of 2016 amounted to 4,794 MW (increasing by 288 MW in comparison to the end of 2015). According to the European statistics, 34 MW of the 288 MW new installed capacity came from the wind power plants and the rest came from hydropower.[17] The biggest share was covered by hydropower plants (approximately 45 per cent), with an annual production of 6.3 TWh (approximately 55 per cent of the total generation). Households consume around 40 per cent of the electrical energy in Croatia, leaving 60 per cent for industry, transport, commercial and public services.

Figure 3.
Consumption of electric energy across sectors (%)



Source: Karanović & Nikolić[8]

In the first half of 2017, the average electricity price, including all taxes, levies and VAT, for an annual consumption of 2,500-5,000 kWh per household was 11.96 EUR cents (¢US 13.85) per kWh. This price represents a decrease of over 10 per cent in comparison to the previous year.[9] Prices generally vary with the amount of electricity consumed. Large consumers such as businesses and industries benefit from the lower prices.

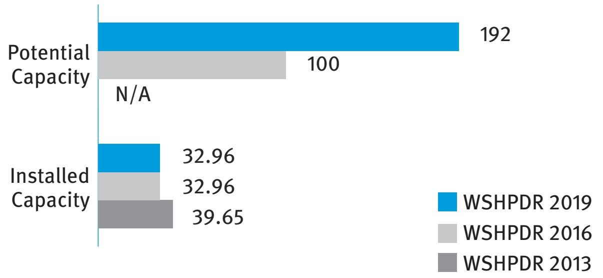
The Croatian Energy Regulatory Agency (HERA) is an autonomous, independent and non-profit public institution which regulates energy activities in Croatia. HERA's obligations, authorities and responsibilities are based on the Act on the Regulation of Energy Activities, the Energy Act and other acts regulating specific energy activities. On 1 January 2016, a new act on renewable energy high-efficiency and combined heat and power (RES Act) came into force and introduced a premium tariff support scheme for these technologies.[9]

Small hydropower sector overview

Small hydropower plants (SHP) are defined as plants having an installed capacity of less than 10 MW. There is a total of 31 SHP plants on grid in Croatia, with a total power installed of 32.96 MW. Out of these, 11 plants with a total installed capacity of 3.9 MW benefit from the feed-in tariff (FIT) system, with a total annual generation of 16,768 MWh. Compared to the total consumption in 2016 of 17,674 GWh, the share of small hydropower amounts to 0.98 per cent of all renewable energy sources in Croatia. Figure 4 offers more details on the installed capacity and the estimated potential capacity of SHP in Croatia. The substantial increase we observe in potential capacity is due to the recently issued locations with a rich small hydropower potential, but also due to new data made available.[12]

Between 2007 and 2016, HERA issued final approvals for privileged hydropower producers for 15 locations, with an installed power of 141.3 MW. Two preliminary and five final approvals were issued in 2016.[10] Total hydropower potential in Croatia is estimated at 20 TWh per year. The possibility of using a large part of the unused potential will depend on the harmonization of the interests of Croatia and its neighbouring countries. Part of the hydropower potential will remain unused due to ecological and other constraints. Therefore, it is estimated that 3.0 TWh per year can be used in new power plants of diverse sizes.[11]

Figure 4.
Small hydropower capacities 2013/2016/2019 in Croatia (MW)



Source: *WSHPDR 2013*,[15] *WSHPDR 2016*,[16] Sofianos[12]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019.*

In the Cadaster of Small Water Resources, 699 spots (at 63 watercourses) have been estimated for an approximate total installed power of 177 MW; 144 MW suitable for plants of 5 MW and 10 MW are still undeveloped, and a technically usable energy potential of 570 GWh. For treated watercourses, the total natural gross power is 15 MW for plants below 5 MW, with a gross energy potential of 130 GWh. The gross potential for small hydropower is estimated at 192 MW. By eliminating the moves of smaller geodetic falls, it is realistic to assume that there are about 350 technically usable moves, and that the number will be further reduced due to the local urban conditions and ecological requirements.[12]

The main permits required for SHP include:

- Environmental permit: In the case of SHP plants above 5 MW a full assessment may be performed if the Ministry of Environmental Protection, Physical Planning and Construction decides that it is necessary.
- Building Permit: For SHP the developer must obtain a single decision, allowing the construction of a facility.
- Permit to exploit natural resources: An energy permit (*energetsko odobrenje*) is required for the construction of all facilities, except for solar power plants integrated into rooftops and the walls of buildings.[12]

To be less dependent on energy imports, Croatia would need some 450 MW worth of additional installations in hydropower. Hrvatska Elektroprivreda (HEP), the Croatian power utility, is planning the construction of a hydropower plant in Jasenica with the capacity of 300 MW. The construction should be completed by 2020. Another possibility would be HPP Novo Virje, with a planned capacity of 138 MW. A major project is "Zagreb na Savi". Using the total potential of the Sava River of approximately 150 MW around the area of the Croatian capital, the energy facilities of the new Zagreb on the Sava construction concept have an annual production of approximately 630 GWh, all from renewable energy sources. This would cover 25 per cent of the annual consumption of the city of Zagreb.[14]

Renewable energy policy

A new tariff system was introduced in 2014 which basically reduced the support for wind and solar power plants. The Market Premium Model was finally introduced in 2014 for renewable energy sources. The quota until 2020 was established at 35 MW of small hydropower, and 744 MW of wind power plants connected to the grid. To reach the hydropower target, 11 power plants with a combined power of 3.9 MW were installed. There are additionally pending contracts with an installed capacity of roughly 4.2 MW.[14]

Croatia offers four different types of support scheme for renewable energy projects. Of primary importance for RE producers is the Tariff System for the Production of Electricity from Renewable Energy Sources and Cogeneration. The announcement of this specific scheme was published in the Official Gazette in 2013, 2014 and 2015 respectively. Financial support for renewables projects include:

- The "environmental protection loan scheme," issued by the Croatian Bank for Reconstruction and Development (HBOR), and conducted with commercial banks;
- Financial incentives as interest-free loans or subsidies are offered by the Environmental Protection and Energy Efficiency Fund (FZOEU).[18]

Table 1.
Premium tariff for renewable energy

Energy type	*Size*	*Incentive price (US$/kWh)*
Hydropower	<300 kW	0.17
	300 kW -2 MW	0.15
	2-5 MW	0.14
Wind power	>5 MW	*RC
Biomass	<300 kW	0.21
	300 kW -2 MW	0.20
	2-5 MW	0.19
	>5 MW	*RC
Geothermal		0.19
Biogas	<300 kW	0.22
	300 kW – 2 MW	0.20
	2 – 5 MW	0.19
	>5 MW	*RC

Source: HROTE[14]

Note: * RC = reference price. For each accounting period, plants that have the incentive price of RC will be paid the amount of currently valid RC.

Renewable energy plants that have obtained the status of privileged producer and have subsequently won a public tender carried out by the Croatian Energy Market Operator may receive for a period of 14 years a premium on the tariff of up to the amounts outlined in Table 1.

Barriers to small hydropower development

There are several bureaucratic, environmental, financial, and quotas-related barriers to the development of SHP plants in Croatia:

- Construction needs to follow strict environmental rules and procedures that are not defined clearly and are general to hydropower of all sizes. There are several state agencies responsible for obtaining permits for development and construction of SHP plants, which complicates the whole process.
- Funds are limited, due to high upfront investment and long payback period.
- There is no reliable plan with the exact locations for possible small hydropower plants, which would be necessary for developing and planning SHP plants in very early stages.
- As the renewables target for Croatia was already reached, there is to a lesser extent a necessity for political support for new SHP projects.[13]

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4.3.4 Greece

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Key facts

Population	10,760,420 [1]
Area	131,954 km[2]
Climate	Greece has a Mediterranean temperate climate, with mild, wet winters and hot, dry summers. The year can be divided into two main seasons – the cold and rainy period, which lasts from mid-October until the end of March, and the warm and dry season, which lasts from April to October. The coldest months are January and February (average minimum temperatures are between 5 and 10 °C in coastal areas and 0 to 5 °C in inland areas). In the north part of the country the winter is much cooler, with temperatures occasionally falling as low as -20 °C. In the months of July and August, the average maximum temperatures lie between 29 and 35 °C.[2,15]
Topography	Greece is a peninsular country, with an archipelago (Aegean) of about 3,000 islands. Greece's coastline measures almost 15,000 km, including islands. Greece is one of the most mountainous countries in Europe, with 80 per cent of its area covered by mountains. This justifies the existence of an appreciable hydropower potential. The Pindus mountain range lies across the centre of the country in a north-west-to south-east direction, with a maximum elevation of almost 2,650 metres. Central and western Greece feature high and steep peaks intersected by many canyons and other karstic landscapes, including the Meteora and the Vikos Gorges - the latter being one of the largest in the world, plunging vertically for more than 1,100 metres. Mount Olympus is the highest point in Greece, rising to 2,919 metres above sea level.[2,15]
Rain pattern	Rainfall in Greece even during winter does not last for many days and winter storms usually end during mid-February. Average annual precipitation varies from 500 to 1,200 mm in the north-west and from 380 to 800 mm in the south-east.[15] Cyclades islands are the driest area of the country.[2]
Hydrology	The most important rivers in Greece are the Evros, Nestos, Strimon, Axios, Aliakmon, Penios, Arachtos, Acheloos, Sperchios and Alfios. The Acheloos has a considerable water flow of approximately 300 m³/sec during December, while the flow rate of Axios is almost 230 m³/sec in March. Finally, the flow rate of Evros varies between 200 and 220 m³/sec from January to March. Total domestic water resources are estimated at 85 TWh/year while the annual specific theoretical hydrodynamic potential of Greece accounts for 0.73 GWh/km². The technically and economically exploitable hydropower potential is estimated at an annual level of 21 TWh/year.[3,15]

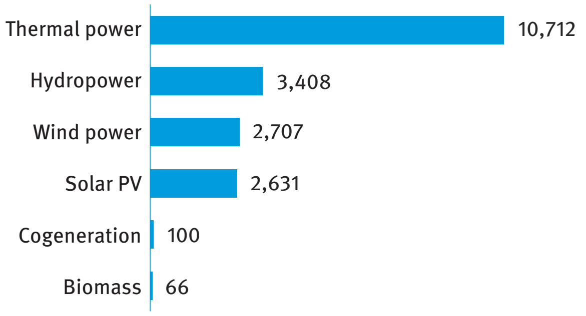
Electricity sector overview

The national Electricity Generation System (EGS) is divided into two main sectors – the interconnected system of the mainland and the autonomous power plants of the Aegean Archipelago islands. In July 2018, the installed capacity in Greece was approximately 19,624 MW. Total installed capacity was calculated by taking into consideration the installed capacity of the interconnected system of the mainland (17,330 MW) and the installed capacity of the Greek islands, including Crete and Rhodes (2,291 MW). The 17,330 MW mainland system includes natural gas (5,000 MW from five power stations of the Public Power Corporation (PPC) and from nine power stations belonging to private companies), renewable energy sources (RES) (5,260 MW, including wind power, solar PV stations, small hydropower, biomass and Cogeneration), lignite (3,904 MW from 14 power stations after the decommissioning of Ptolemais lignite power station), and large hydropower (3,171 MW). At the same time, in the Greek islands including Crete and Rhodes 2,291 MW is in operation, including diesel and heavy oil power stations (1,808 MW), and renewable energy plants (483 MW-including wind power, solar PV stations, biomass and one small hydropower plant of 0.3 MW at Crete island). Figure 1 offers more details on installed electricity capacity by source in Greece.[5]

The amount of imported natural gas for thermal power stations is gradually increasing, the majority belonging to private electricity production companies trying to enter the local market. During 2018, lignite power units contributed to almost 30-35 per cent of the electricity production on an annual basis. The total electricity generation in Greece (excluding Crete and Rhodes) was approximately 51 TWh in 2017, remaining almost constant in the past five years and 20 per cent lower than the values of the previous decade.[5]

In 2017, the electricity production of the autonomous islands (including Crete and Rhodes) was almost 6.1 TWh, out of which 1.1 TWh (approximately 17 per cent of the total production) resulted from the operation of the renewable energy sources-based power stations.[6,7] Across the interconnected system (excluding Crete and Rhodes) the share of renewable energy sources (RES) (including large hydropower) was approximately 30 per cent in 2017. Recently, the installed RES-based capacity exceeded 8.4 GW, although the SHP contribution remains almost constant.[6,7] The electrification rate in Greece is 100 per cent. Total consumption was 43,918 GWh or almost 44 TWh in 2017.[6]

Figure 1.
Installed electricity capacity by source in Greece (MW)



Source: OEM[5]

The significant increase in GDP between 2000 and 2008 was accompanied by a corresponding increase in electricity consumption which peaked at 57 TWh in 2008. Subsequently, the economic crisis led to a significant decline in consumer activity resulting in the reduction of both GDP and electricity demand for 2014 down to the levels of 2000. Since then GDP and the electricity consumption have remained almost constant at the 2014 levels. Given the continuing economic uncertainty, the demand for electricity is not expected to recover any time soon. During the evening of 25 January 2018 the interconnected grid peak demand was 8,371 MW.[8]

A series of legislative reforms were attempted, in order to liberalize the state monopoly in the electricity sector. The undertaken efforts have not led to major changes. The Public Power Corporation (PPC) maintained its dominant position in the electricity sector (almost 68 per cent of the market). A significant increase in imports of cheap electricity from the Balkan countries, neighbouring Greece in the north occurred, to meet the demand for the next 24-hour period. During the first half of 2018, net electricity imports approach 3.5 TWh, accounting for 16 per cent of the domestic energy consumption.[5,8]

In recent years, the electricity sector has been characterized by several factors including the pressure of withdrawing, due to environmental and economic grounds, the old thermal units. The lignite fired plants of Megalopolis and Ptolemais have been decommissioned. Four additional ones of Aminteo and Kardia are preparing to start the decommissioning process by 2020.[9] The rapid penetration of 2,500 MW from solar photovoltaic plants in just two years (due to the particularly high feed-in tariffs (FITs)), and the support provided for the creation of large wind farms, mainly in the Greek archipelago islands, along with the extensive plans for subsea interconnection of the islands with the mainland has been highly beneficial to the renewable energy sector.

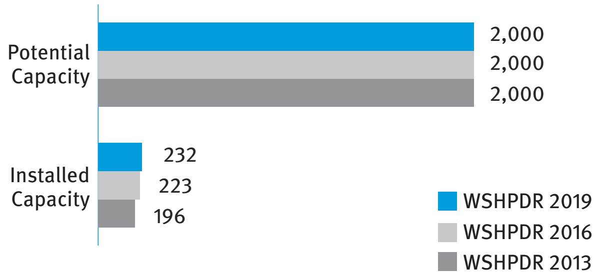
Although, the current political leadership of the Ministry of Environment and Energy supported the creation of new lignite fired power plants (one new lignite fired power station is under preparation at Ptolemais), the protests of environmental organizations and the unfavourable economic situation coupled with the significant decrease in demand for electric power are expected to delay the implementation of similar projects. Moreover, in the context of the European objectives for 2020, Greece will have to cover 40 per cent of its domestic electricity consumption from renewable sources.[19] At the end of 2017, the renewable energy contribution did not exceed 27 per cent.

While the cost of electricity generation is based on the respective System Marginal Price, the price of electricity to consumers is implicitly controlled by the government, thus the marginal production cost for the interconnected system varies between 50 and 90 EUR/MWh (between 57 and 103 US$/MWh), with an average value of 60 EUR/MWh (68 US$/MWh). Finally, it is worth noting that since 1994 there has been a predetermined purchase price of electricity from RES, whose absorption by the electrical system is prioritized unless technical constraints appear. For example, considering the case of the production of small hydropower (SHP), relative price varies at the levels of 90 EUR/MWh, (103 US$/MWh) adjusted every year through ministerial decree.[15] For example, during the first semester of 2018 the electricity price of SHP was 87 EUR/MWh (99 US$/MWh). Recently, the FIT system was abandoned for new RES-based power stations and a new feed-in premium (FIP) scheme has been introduced.

Small hydropower sector overview

The definition of small hydropower in Greece is up to 15 MW. Installed capacity of small hydropower by the end of June 2018 was 232 MW while the economic potential is estimated to be 2,000 MW, indicating that approximately 11 per cent has been developed. Between 2016 and 2018, the installed capacity has slightly increased by 9 MW and the potential capacity has not changed. From data available in Greece, approximately 115 SHP stations of around 2 MW each operate under official licences. Their total installed capacity is 232 MW, which accounts for 7.3 per cent of total hydropower installed capacity. During 2009, installed SHP capacity was approximately 182 MW, demonstrating a limited increase of installed capacity in the range of 7 MW/year, which corresponds to the creation of 5-10 SHP plants annually. From the total installed capacity, only 95 MW corresponds to projects with a nominal output of more than 5 MW, while the rest 137 MW are composed of mini- and micro- projects with nominal power below 1 MW.[16]

Figure 2.
Small hydropower capacities 2013/2016/2019 in Greece (MW)



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

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

Note: Data is for plants up to 15 MW.

Correspondingly, the annual electricity production from SHP is increasing slightly from 0.66 TWh in 2009 to 0.72 TWh in 2016. The generation from small hydropower decreased to 0.59 TWh due to the dry 2017. The estimated average load factor of SHP projects varies between 29 per cent in 2017 and 37 per cent in 2016, almost three times the corresponding value of large hydropower stations in the same period.

A large portion of water resources is concentrated in the western and northern parts of the mainland where one may find the majority of hydropower plants installed. Similarly, the vast majority of SHP stations is located in the northern and western parts of the country. Regarding the geographical distribution of SHP plants, the majority of them are located in Central Macedonia (exploiting the waters of the rivers from the north), Epirus (exploiting the rugged terrain of the region) and western Greece in general.[15] More specifically 50 MW of SHP are installed in Central Macedonia, 49 MW in Epirus, 46 MW in Western Greece, 32 MW in Sterea (Central) Greece, 27 MW in Thessaly, 19 MW in Western Macedonia, 4 MW in Peloponnesus and another 4 MW in East Macedonia-Thrace, Attica and Crete.

The national installed SHP capacity target for 2020 is 350 MW. Therefore, there is a significant number of projects awaiting implementation. Approximately 60 new projects, reaching a total of 200 MW, have already obtained binding connection offers, while more than 300 MW are under approval. According to the current estimates of implementation, by 2020 the total SHP capacity will be just over 250 MW, although there are estimations of 252 MW by the end of 2019 from the national Operator of Electricity Market.[5]

Although SHP projects do not face significant environmental problems or social reaction as is the case with large hydroelectric plants, the development of which faces serious obstacles in Greece, there is no serious state encouragement for SHP implementation either.[10] The initial development cost of a SHP plant ranges from 0.8 million EUR/MW to 1.5 million EUR/MW (0.9 to 1.7 million US$/MW) with the most likely value corresponding to 1.2 million EUR/MW (1.4 million US$/MW).[11,12] During the previous decade, state subsidization of SHP projects accounted for up to 40 per cent of the initial capital for new SHP projects.[11] Nowadays, although there are incentives for SHP projects, the prices of produced electricity are low. However, SHP projects are still an economically efficient investing option, as attested to, by the current high investment interest.

Renewable energy policy

The Greek Government, since implementing the European policy for independence from imports and reduction of environmental impacts of fossil fuels, officially supports the further penetration of RES in the domestic energy balance. In this context, some ambitious and often poorly rated objectives have been set up, which mainly included the massive installation of large wind farms (estimated installed power 7-8 GW by 2020) and encouraged the installation of solar photovoltaic panels (estimated installed capacity by 2020 of 2.5 GW). [15] In both cases, the estimates have experienced serious problems, in particular the lack of infrastructure of electrical networks and negative social reactions to the establishment of large wind farms have limited the installed wind power to 2.8 GW, throughout 2018.

Correspondingly, the installed capacity of solar PV panels by the end of 2017 was almost 2,650 MW and thus exceeded the targets of 2020, bringing the State to a position of limiting the uncontrolled dynamics of the domestic market by both reducing dramatically the electricity purchase price (which in 2012 was 0.5 EUR/kWh or 0.6 US$/kWh) and by imposing a retroactive taxation of 30 per cent on revenue of solar PV plants for the years 2012 and 2013.[13] In this context, the utilization of water resources experienced the lack of governmental interest, as large hydropower faced persistent reaction of local communities and small hydropower was not considered capable to significantly change the energy mix of the national production.[15]

In 2016, the Greek Parliament approved a new law on the renewable energy sector. Aiming to reform the energy sector, the new law allows feed-in premium schemes, competitive tenders and virtual net metering. Following the new law implemented, a series of actions were taken:

- A pilot tender for solar PV plants specifically was planned for 2016, and a number of pilot and regular tenders for large-scale wind power and solar PV installations took place in 2017 and 2018.
- New scheme to approve all renewable energy capacities is based on competitive tenders.
- Virtual net metering is allowed for any type of renewable energy, however the access to it was limited to certain institutions such as: the city and regional councils, educational institutions, farmers and farming associations.[17]

The previous feed-in tariff scheme closed on 31 December 2015 and was replaced by the aforementioned law. The Government granted priority with regards to the use of the grid for renewable energy dissemination.[18]

Barriers to small hydropower development

There are multiple barriers to small hydropower development in Greece. Some of the major drawbacks decelerating SHP penetration in the local electrical market are the following:

- The administrative bureaucracy: There is a lengthy process (usually up to three years) to obtain the final licence required for commencing construction.[12]
- The absence of an integrated national water management plan: Electricity production through small hydropower might be affected by the lack of a water management plan, as local municipalities and agricultural cooperatives can take advantage and exercise pressure on the utilization of the available water resources.
- Taking into account the relatively small size of the above-mentioned installations and the corresponding limited budget, most big energy-related construction companies are not showing much of an interest in similar small size projects. As a consequence, SHP development is mostly realized by small private companies, which frequently come across multiple challenges such as: limited budget, lack of expertise and knowledge on the sector.

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4.3.5 Italy

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Key facts

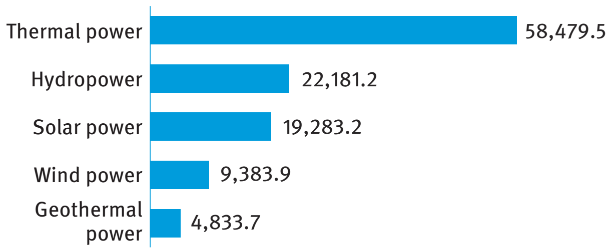
Population	60,494,000 [1]
Area	301,340 km²
Climate	Northern Italy experiences cold winters, and hot and humid summers. Winters in central Italy are milder, whilst there are very hot summers and very mild winters in the south and the islands. Average temperatures are 3 °C (north) – 14 °C (south) in January and 28 °C (north) – 30 °C (south) in July. [1]
Topography	The territory is mostly mountainous. The Alps form the northern boundary of the country and the Apennine Mountains represent the backbone of the peninsula. The largest plain is the Po Valley (71,000 km²) and the highest peak is Mont Blanc (4,810 metres above sea level).[1]
Rain pattern	Mean annual rainfall is about 1,000 mm. The highest values occur in the north-east (>2,500 mm). On the islands and in the south, the rainfall rarely exceeds 500 mm per year.[1]
Hydrology	Italian rivers are numerous (around 1,200) but generally shorter than in other European countries. This is due to the relatively small distance between the mountains and the sea. All rivers have catchments entirely within the country. The longest river is the Po (652 km). Other water sources are glaciers in the Alps.[1]

Electricity sector overview

In 2016, Italy generated 277,235 GWh of electricity, which satisfied about 88.2 per cent of the national demand (314,261 GWh).[2] Imported electricity compensated the remaining fraction (43,181 GWh).[2] Renewable sources (hydropower, solar and wind) have become increasingly important since 2011, therefore reducing the use of fossil fuels.[2]

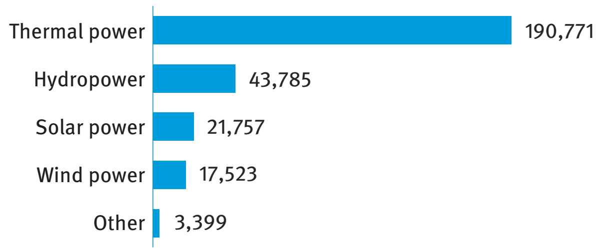
Net installed generation capacity in 2016 was 114,161 MW (2.4 per cent less than in 2015), which includes thermal (58,479 MW), hydropower (22,181 MW), solar (19,283 MW), wind (9,383 MW) and other sources (4,833 MW). As of July 2016, minimum and maximum annual grid loads observed in the same year were 18.7 and 53.5 GW.[4] Maximum annual grid load in recent years has moved from winter to summer, due to the increasing use of air conditioning in summer.

Figure 1.
Installed electricity capacity by source in Italy (MW)



Source: Terna[7]

Figure 2.
Annual electricity generation by source in Italy (GWh)



Source: Terna[7]

Italy's national electricity demand in 2016 showed a slightly decreasing trend (-0.8 per cent compared to 2015). However, it did not affect the growth observed in previous years (+2.0 per cent compared to 2014). This is linked strongly with an ongoing recovery of the country from an economic recession. In 2016, the Gross Domestic Product (GDP) increased (+0.9 per cent) for the second consecutive year (+0.8 per cent in 2015).[3]

In Italy, private companies manage the production, transmission and distribution of electricity. Competition in these sectors is allowed, promoted and regulated by the Authority of Electricity and Gas (AEEG, Law 481/1995). Terna S.p.A. is the Transmission System Operator and owns 99.7 per cent of the whole National High Voltage Transmission Grid (72,844 km). Since 2014, 11 other companies are involved in low-voltage grids management at regional scale. In 2016, 135 distribution companies were employed. In particular, Enel Distribuzione S.p.A. provided electricity to the largest portion of domestic and industrial users (85 per cent).[3]

Approximately 6 per cent of the produced electricity was lost along transmission and distribution networks (18,753 GWh).[2] Moreover, several connection lines are now inefficient and often suffer from congestion. Therefore investments are needed to improve the aging energy infrastructure in order to increase the efficiency of networks and guarantee power supply for new users. The electrification rate is 100 per cent.

The Government's plans mainly involve the reduction of fossil fuels for electricity production and the safety of power supply, which is highly sensitive to global political stability (e.g. instability in Libya has caused 32 per cent of less oil import from this country). Consequently, the diversification of sources for energy production and the promotion of renewable energy (RE) are objectives of the Government.

The first regulated electricity market in Italy was introduced in 2004. The electricity market, commonly called Italian Power Exchange (IPEX), enables the producers, consumers and wholesale customers to enter into hourly electricity purchase and sale contracts. The market, regulated by the Energy Market Manager (GME), mainly consists of the Day-Ahead Market (MGP) where electricity for the following day is traded. GME is the central counterparty in the transactions at the MGP. Sell/purchase proposals may change during the following electricity market sections.

In 2016, the Italian electricity market was characterized by a mean energy price of 43 EUR/MWh (51 US$/MWh), with a decrease of 18.2 per cent compared to 2015 (the lowest since the introduction of the market).[6] This decrease in the energy price could be explained by the fall of oil price (less than 50 US$ per barrel) and the growth of renewable sources of energy. Despite the decrease in the price of energy in Italy, it still remains higher compared to other European markets. Italy heavily relies on natural gas for the production of electricity and therefore electricity price is significantly influenced by the natural gas price. [6]

Small hydropower sector overview

Small hydropower (SHP) plants are classified according with their maximum capacity as:

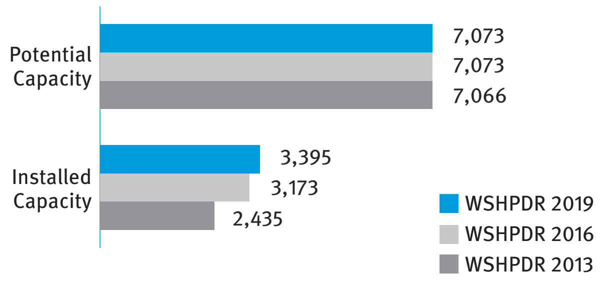
- Micro-hydropower: P < 0.1 MW;
- Mini-hydropower: 0.1 MW ≤ P < 1 MW;
- Small hydropower: 1 MW ≤ P < 10 MW.

As of 2018, the latest data update registered that in Italy there were 2,745 micro- and mini-hydropower plants in operation with an installed capacity of 769 MW, whereas there were 872 small hydropower plants (2,626 MW) (Figure 3).[7]

Italy is one of the three major Southern Europe producers of hydroelectric energy, along with Spain. The energy produced in 2016 was 13,142 GWh (3,308 GWh by micro- and mini-hydropower and 9,834 GWh by small hydropower). The number of micro- and mini-plants rose by 7.6 per cent compared to 2015, and the number of small plants rose by 2.1 per cent. The same comparison in terms of energy produced is meaningless as inter-annual climatic fluctuations strongly affect the water resources available for hydropower plants.

Large hydropower plants (P ≥ 10 MW) still represent the most important source of hydroelectricity. In fact, large hydropower plants produced about 42,062 GWh in 2016 (76 per cent of the total hydropower generation) whereas small hydropower plants contributed the remaining 24 per cent (13,142 GWh).[9]

Figure 3.
Small hydropower capacities 2013/2016/2019 in Italy (MW)



Source: Terna,[7] *WSHPDR 2016*,[5] *WSHPDR 2013*[8]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

The gross theoretical capacity of water resource use for energy production is based on the calculations accounting for topography and precipitation in each country. The gross HP potential in Italy is estimated to be about 200 TWh/year, of which 38 TWh/year associated with SHP. Net potential also includes the technical and economic feasibility of hydropower production in the assessment of the residual potential. Technical and economical constraints reduce the HP potential production to about 50 TWh/year. Estimates of the technical SHP potential range between 12.5 TWh and 20 TWh. The potential installed capacity available is around 3,900 MW.[9]

The National Energy Strategy (2017) forecasts the overall hydropower production of 50 TWh by 2030. This goal will be reached mainly by supporting the revamping of large hydropower plants (some of them were built 100 years ago) and the construction of new SHP plants.[10]

The development of Italian hydropower production in the 20th century has been typically associated with the construction of conventional plants that rely on large dams, which induce changes in the landscape and significant alteration of river flow. However, conventional HP plants are close to saturation in most EU countries, including Italy. The unexploited HP potential is thus associated with SHP. This sector has become increasingly important during last decade thanks to government policies that have fostered the installation of new SHP plants beyond any expectation.

SHP growth has been driven by comprehensive feed-in tariffs (FITs) (0.22 EUR/kWh (0.26 US$/kWh) for 15 years) introduced in 2008 as an alternative to Green Certificates for plants with a capacity up to 1 MW.[12] These incentives have strongly promoted new SHP plants, but the cost of this strategy is still being paid by the Italian Government which has recently started a gradual reduction of feed-in tariffs for SHP that will likely make new SHP plants affordable only in the case of self-production.

In June 2016, a ministerial decree introduced a new support scheme for SHP plants. FIT (and subsidized period) depends on the maximum capacity (P):
- 1<P≤250 kW: 210 EUR/MWh (249 US$/MWh), 20 years;
- 250<P≤500 kW: 195 EUR/MWh (231 US$/MWh), 20 years;
- 500<P≤1,000 kW: 150 EUR/MWh (178 US$/MWh), 20 years;
- 1000<P≤5,000 kW: 125 EUR/MWh (148 US$/MWh), 25 years;
- 5000<P≤10,000 kW: 90 EUR/MWh (106 US$ /MWh), 30 years.[11]

However, the ministerial decree prescribes the maximum annual installed capacity for each source of energy. In particular, no more than 80 MW of annual hydropower capacity can be installed each year. If new SHP projects exceed the annual capacity threshold, plants are ranked and FITs are guaranteed only for those having less environmental impact. This mechanism was not applied until 2018 to plants smaller than 100 kW, which could directly access incentives.[11]

Renewable energy policies

Italy has placed the growth of renewable sources of energy (RE) among the priorities for the development of the country's energy sector. According to the EU directive 2009/28/CE, in 2020 the 17 per cent of the total electricity demand of the country will be provided by RE. However, this goal had already been achieved by the country in 2014 (17.1 per cent in 2014, 17.5 per cent in 2015, 17.4 per cent in 2016 according to the Energy Market Manager).[13] This goal is specified for different sectors as:
- Electricity production by RE: 26.4 per cent by 2020 (actual value: 34.0 per cent in 2016);
- Use of RE for transports: 10.0 per cent by 2020 (actual value: 7.3 per cent in 2016);
- The National Renewable Energy Action Plan (SEN 2017) has recently introduced new, ambitious targets for renewable energy development;[10]
- Elimination of fossil fuel in the electricity production by 2025;
- Elimination of fossil fuel in the energy production by 2050, that will be reached by increasing the renewable sources of energy to 27 per cent of the whole production by 2030;
- The National Energetic Strategy 2017 defines the expected growth from 2015 to 2030 of the installed capacity and the electricity production for each renewable source.[10] The key players for increasing the renewable electricity production are mainly PV and wind energy. The annual production of hydroelectricity is planned to increase from 46 TWh (2015) to 50 TWh (2030) by maintaining high efficiencies of the existing plants.[10]

Moreover, RE will play an important role in reducing CO_2 emissions by 40-70 per cent by 2050, compared to 2010 emission levels. This target was established at the G7 summit in June 2015 and will lead to the decarbonization of the global economy over the course of this century in Italy as well as in other countries worldwide.

RE incentives schemes are based on the share of electricity which is fed into the grid. New plants receive incentives based on their size:
- P < 1 MW: FITs;
- P > 1 MW: the incentive is based on the difference between a reference tariff and the zonal price of energy.

Access to incentives is based on the registration on a priority list by which the annual additional capacity is controlled (<80 MW for hydropower).

Several RE development schemes exist in Italy. The total cost was EUR 14.2 billion in 2017 (US$ 16.8 billion). [13]

- *CIP6/92*
  CIP6/92 is the first mechanism of incentives for RE adopted in Italy. It is no longer in use for new plants, but there are previously built plants still supported (21 plants in 2016).

- *CE*
  This scheme is specific for PV. CE price depends on the share of electricity self-consumed and inserted in the grid. Annual incentives by CE are capped at 6.7 billion EUR (8 billion US$). This limits the number of new PV plants that can benefit from this scheme.

- *Green Certificates (1999)*
  New RE plants receive a number of GC according with their energy production (1 GC = 1 MWh). GC can be sold to industries that are forced to produce a fraction of energy with the renewable sources, but are not able to do it on their own. GC average annual price ranges between 80 and 120 EUR/MWh (excluding VAT; 95 and 142 US$).[6]

- *FITs (2008)*
  FITs include electricity price and incentive. They are guaranteed for several years after the activation of the plant. Small producers usually prefer this support scheme because GC markets can be very complex. FITs simplify financial planning for plants with a small capacity.

Barriers to small hydropower development

Although it is still an important source of electricity, strong additional developments of hydropower are not expected in the next years for Italy. The Government's plan for large

HP mainly involve the refurbishment of existing plants, which are 50 years old on average. Construction of new large plants is contrasted by the absence of suitable sites and by the strong impact that this kind of plants might cause in a heavily populated country. Energy production by the small hydropower is not expected to increase despite the unexploited potential. Key players are represented by wind energy and PV.[5]

Main barriers to SHP development regard:

- *Tariffs*

  The recent adoption of a new ministerial decree on SHP (June 2016) has strongly decreased FIT for this kind of source of renewable energy compared to 2012. Payback periods have consequently been extended and this will certainly discourage investors.

- *Authorization process*

  The authorization process in Italy takes 2-3 years on average. Permissions (water concession, construction licence, etc.) are granted by different departments. Moreover, there is no substantial difference between the water concession for small hydropower and large hydropower plants. Finally, the recent introduction of a threshold on the annual installed capacity (and consequently the ranking procedure for competitive plants) has further slowed down the process.

- *Environmental requirements*

  Even though SHP inflicts a smaller impact on aquatic ecosystems and local communities compared to the large dams, it cannot prevent stresses on plant, animal, and human well-being. Additionally, the negative cumulative effect of SHP plants operating along the same river threatens the ability of stream networks to support biodiversity. Currently, the prediction of the long-term impacts associated with the expansion of SHP projects induced by the global-scale incentive policies remains highly uncertain.

  Although limiting for HP exploitation, environmental regulations are needed to preserve river networks. An example is the release of the Minimum Environmental Flow (MEF), which was established by Water Authority. Weirs crossing the river must also be equipped with fish passages allowing migration. Moreover, SHP plants with a capacity larger than 100 kW are forced to undergo Environmental Impact Assessment (EIA).

  Given the recent expansion of SHP plants in Italy and the disturbance on riverine ecosystems, an emphasis must be placed on combining the energetic/monetary needs with the environmental preservation. Small hydro-technology is likely to gain a higher social value in the next decades if the environmental and hydrologic footprint associated with the energetic exploitation of surface water will take a higher priority in civil infrastructure planning.

- *Social conflicts*

  Social movements against SHP are growing in Italy, especially in the northern part (the Alps). Usually concentrated in less developed, mountainous areas, hydroelectricity generation is associated with negative externalities in proximity to the plants, and the downstream communities get most of the benefits. The goal of these movements is to prevent further exploitation of the mountainous river networks that are already altered by the water regulation due to dams. There are examples of new SHP plants that have been stopped or which construction was delayed because of this opposition.

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4.3.6

Montenegro

Igor Malidzan, Energy Regulatory Agency Montenegro

Key facts

Population	622,387[7]
Area	13,812 km^2 [7]
Climate	The Montenegrin climate is characterized by hot dry summers and autumns and relatively cold winters, with heavy snowfall inland.[12] It has a Mediterranean climate in the South and a Continental climate in the North.[8] The highest average temperature is in July with 18.9 °C and the lowest average temperature is in January with –1.5 °C.[13]
Topography	Due to its position between the Balkan Peninsula and the Adriatic Sea, Montenegro has some of the most rugged terrain in Europe and diverse topography, with coastal plains at the Albanian border and tall peaks by the Serbian border. Montenegro's most notable mountains include the Durmitor range, Mount Orjen and Mount Lovcen. The highest point, Bobotov Kuk, at 2,522 metres is located in the Durmitor range.[14]
Rain pattern	Mean annual precipitation of the country is 1,138 mm. Rainfall is the highest in November, with an average rainfall of 123 mm. Rainfall is the lowest in August, with an average rainfall of 66.3 mm. The lowest precipitation is in the North and the highest in the central regions, where continental and Mediterranean climate conditions meet.[13]
Hydrology	The Drina, Tara and Lim are amongst the most significant rivers in Montenegro, its largest lake is Lake Skadar, and is shared with Albania. On its east coast, along the Adriatic Sea, a prominent element is submerged river canyon known as the Bay of Kotor.[14]

Electricity sector overview

In 2016, the main energy resources used in Montenegro for producing electricity were hydropower and thermal power (coal), Figure 1 shows the electricity generation by source. There are also plans for using other energy sources such as wind, solar, biomass, which are still under development.

Figure 1.
Annual electricity generation by source in Montenegro (GWh)

Source: Energy Regulatory Agency[1]

Based on 2016 numbers, the total installed capacity of power plants operating within the Montenegrin energy system is 893 MW, where coal-thermal power plants contribute 24.47 per cent (218.5 MW) and hydropower plants contribute 75.53 per cent. Hydropower is exploited by two large hydropower plants, Piva (342 MW) and Perucica (307 MW), as well as 16 small hydropower plants (a combined installed capacity of 25.33 MW). The electricity generation from the main power plants are shown in the Table 1.[1]

Montenegro has a 100 per cent electrification rate. In 2016, the share of electricity generation by hydropower was around 60 per cent.

Montenegro is a candidate country for the European Union (EU) and a contracting party of the Energy Community Treaty. As such, it has an obligation to follow EU policy for energy and environment. The new Energy Law (2016) is fully in line with the Third Energy Package, as well as its bylaws.[12]

Table 1.
Installed capacity and generation in Montenegro

Power plant	*Installed capacity (MW)*	*Generation (MWh)*		
		2016	*2015*	*2014*
Thermal power "Pljevlja"	218.5	1,216,150	1,411,614	1,322,062
Hydropower "Piva"	342	792,461	631,040	679,338
Hydropower "Perućica"	307	938,730	783,358	1,006,682
Small hydropower	25.33	76,047	45,546	30,596
Total	**892.83**	**3,023,388**	**2,871,558**	**3,038,678**

Source: Energy Regulatory Agency[1]

Elektroprivreda Crne Gore (EPCG) is an energy company which is the main generator in Montenegro. It is a market-based supplier, and at the same time it is the supplier to vulnerable customers. Upon the EU directives, every country is obliged to nominate a supplier of this type. In Montenegro, it is foreseen that this supplier is chosen in a tendering procedure. Previously, EPCG was a vertically integrated company that was also responsible for the transmission and distribution network, until 2009 when Crnogorski elektroprenosni sistem (CGES) was established and became the transmission system operator, and 2016 when Crnogorski elektrodistributivni sistem (CEDIS) was established and it became the distribution system operator. This has unbundled the transmission and distribution responsibilities from EPCG. The State of Montenegro owns the majority shares in all three companies. The main minor shareholders of the three companies are A2A, with 43 per cent of EPCG and CGES, and Terna with 22 per cent of CGES. Both are based in Italy.[1]

The transmission system consists of 110 kV facilities, 110/x kV substations, 110 kV lines, as well as facilities, substations and lines of voltage level higher than 110 kV. A 375 km-long High Voltage Direct Current (HVDC) undersea electricity cable project has been planned. It will connect Italy and Montenegro through converter stations on both coasts and 400 kV overhead lines in Montenegro. Furthermore, interconnection lines to Serbia and Bosnia and Herzegovina are under construction. The realization of the HVDC undersea electricity cable project will allow a 400 kV-line ring to be formed which will contribute to the safety and stability of the transmission system and relieve the 110 kV voltage level system. The structure and geographic disposition enable good connections with neighbouring systems of Serbia (two 220 kV lines and one 110 kV line), Bosnia and Herzegovina (one 400 kV line and two 220 kV lines), Albania (one 400 kV line and one 220 kV line) and Kosovo (one 400 kV line). [1]

The distribution system consists of 35 kV facilities, 35/x kV substations and 35 kV lines, as well as facilities, substations and lines of lower voltage levels. The distribution system is in its final phase of replacement of the old electricity meters with 'smart meters'. This will provide a more advanced management system. CEDIS replaced 263,000 active electricity meters by the end of 2016.[1] New smart meters have a lot of additional functions compared to ''classical'' ones. They can provide a real-time data exchange with the data centre. Currently, only few functions are in use, such as remote registration of consumption, remote and more effective disconnection, detection of unauthorized interventions on meters which could influence on accuracy of measurement. Additionally, the reconstruction of a low-voltage network is ongoing. As a result, the electricity losses from the distribution network (complete losses, technical and so-called commercial losses) are steadily decreasing, from 20.84 per cent in 2012 to 15.61 per cent in 2016.[1]

The electricity market was opened based on the decisions of the Regulatory Energy Agency (RAE) and Energy Law of 2003. It is foreseen that from 2017, the electricity prices for small customers and households will be set by the Energy Law of 2016. All other customers have to buy electricity from the market or choose their supplier. The retail price for distributed consumer categories is calculated based on the active electricity, the engagement of transmission and the distribution capacities, the transmission and distribution network losses, as well as fixed fees for the electricity system operators. RAE is responsible for setting the allowed revenue for the system operators and prices related to the network charges. [1]

Table 2.
Electricity tariffs in 2016 in Montenegro

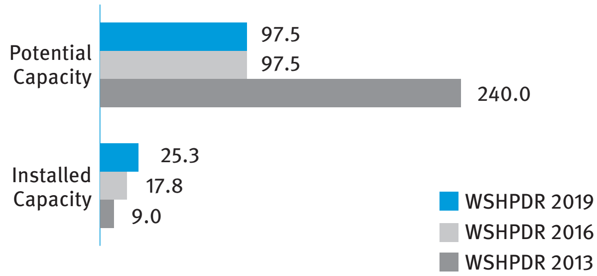
Customer category	*Tariff (EUR cent/ kWh)*
Customers connected to 35 kV voltage level	5.40
Customers connected to 10 kV voltage level	7.32
Customers connected to 0,4 kV with power load measurement	10.89
Households	8.38

Source: Energy Regulatory Agency[1]

Small hydropower sector overview

In Montenegro small hydropower (SHP) is defined a plant with installed capacity of less than 10 MW. At the end of 2016, there were 16 SHP plants in operation, from which seven are 30 or more years old and 9 were built in the last three years. In 2016, overall SHP installed capacity was 25 MW with production of around 76 GWh.[2]

Figure 2.
Small hydropower capacities 2013/2016/2019 in Montenegro (MW)



Source: Energy Regulatory Agency,[1] *WSHPDR 2013*,[10] *WSHPDR 2016*[2]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019.*

In 2007, the Government began giving concessions to private investors for SHP construction. This agreement includes development, construction, operation and maintenance for up to 30 years, after which all the equipment and facilities will transfer to the state ownership.[4]

As of 2015, 46 new privately owned SHP plants, including nine already operational plants, were approved with an overall capacity of 90.68 MW and an estimated energy generation of 295 GWh. Since 2007, six tenders for concessions have been undertaken (see Table 3).[1]

Table 3.
Overview of approved small hydropower plants as of 2015 in Montenegro

Type of agreement	*Number of contracts*	*Number of sites*	*Estimated capacity (MW)*	*Estimated generation (GWh)*
Tender	18	37	83.21	268.55
Energy permit	9	9	7.47	27.63
Total	**27**	**46**	**90.68**	**295.20**

Source: Energy Regulatory Agency[1]

In order to improve and accelerate the authorization process for the renewable energy sources, a new and simple procedure for authorizing the construction of SHP plants with an installed capacity of up to 1 MW was established. Under the current regulation, energy permits can be issued for plants up to 1 MW of installed capacity.

EPCG is planning, as it is foreseen in Energy Development Strategy until 2030, the reconstruction of existing small hydropower plants to 11.4 MW. The Energy Development Strategy includes data from the 2001 Water Master Plan, which estimates the overall theoretical hydropower potential of Montenegro between 10.6 TWh and 10.8 TWh and the technical potential between 5.0 TWh and 5.7 TWh until 2030 (see Table 4).[4]

Table 4.
Theoretical and technical hydropower potential

Source	*Theoretical potential (TWh)*	*Technical potential (TWh)*
Main rivers	9.8	4.6-5.3
Small rivers	0.8-1.0	0.4
Total	**10.6-10.8**	**5.0-5.7**

Source: Ministry of Economy[4]

However, upon taking data from the previous on-site hydrometric measurements at locations on small rivers into account, it appears that these data are an underestimation. By 2014, three series of one-year measurements were finished at approximately 40 locations on 35 rivers.[4] The programme continues and today hydrometric measurements are ongoing. The state of the hydrometric measurement network is continuously improving in terms of the number of automatic hydrometric stations and the quality of the equipment. Therefore, it is expected that the estimated hydropower potential on individual water streams will become more reliable.[4]

Renewable energy policy

The existing generation portfolio relies on the hydropower and coal energy but the "Strategy for Energy Development in Montenegro up to 2030" foresees intensive usage of the wind, solar, and biomass energy and other renewable energy sources as a priority. Hydropower will remain the dominant source, with the wind power contributing significantly as well. Moreover, the National Renewable Energy Action Plan (NREAP) up to 2020 was adopted in 2014, taking into account the Energy Community Ministerial Council Decision D2012/04/MC-EnC, which obliged Montenegro to adopt the Renewable Energy Directive 2009/28/EC and establish a national target of 33 per cent of the total energy consumption and 51.4 per cent of the total electricity consumption from renewable energy sources by 2020.[6] The NREAP also defines the targets for different types of the renewable energy. Total installed capacity from the hydropower plants is planned to total 826 MW with an annual generation of 2,050 GWh by 2020. As well as this, it is intended that by 2020, installed capacity of SHP plants will amount to total of 97.5 MW, with an annual generation of 287 GWh (see Table 5). This means that SHP installed capacity will increase 74 per cent and total SHP potential will be exploited. With the newly approved reconstruction projects expected to increase SHP to 94.8 MW, the country is close to achieving this objective.[6]

Table 5.
National goals for the construction of small hydropower plants up to 2020 in Montenegro

Plant size	*Capacity (MW)*	*Generation (GWh)*
up to 1 MW	11.2	35
1-10 MW	86.3	252
Total	**97.5**	**287**

Source: Ministry of Economy[6]

The Renewable Energy Policy introduced by the Energy Law that was adopted in 2010 was further developed with a new Energy Law adopted in 2016. Renewable energy regulatory framework includes a feed-in tariff scheme based upon European regulations. New energy producers based on renewable sources receive the status of 'privileged producers' for 12 years, entitling them to the feed-in tariffs and priority delivery. From 2016, a new status, 'temporary privileged producer' was introduced. As defined in the bylaw, future producers can get a temporary status of 'privileged producer', which will ensure a guaranteed price as well as all incentive measures at that time, if construction is completed within two years. The feed-in tariffs for SHP are based on the annual electricity generation and favour the construction of smaller facilities (see Table 6).5 The same flat rate feed-in tariff is also implemented for the refurbished SHP plants.[5]

Table 6.
Feed-in tariffs for small hydropower plants in Montenegro

Power at plant's exit (P_{PE})	*Incentive price (EUR cent/kWh)*
P_{PE}<1 MW	10.44
1≤P_{PE}<3 MW	10.44-(0.7*$_{PE}$)
3≤P_{PE}<5 MW	8.87-(0.24*P_{PE})
5≤P_{PE}<8 MW	8.35-(0.18*P_{PE})
8≤P_{PE}<10 MW	6.8

Source: Ministry of Economy[5]

The first column of Table 6 P_{PE} represents the installed capacity of hydropower reduced by losses from the turbine, generator and transformation. The second column shows the incentive price which is calculated based on the power at the plant's exit.

Barriers to small hydropower development

Despite the measures and actions made by the Government in improving the legislative and developmental processes for SHP, many obstacles for developing an attractive environment for investment still remain. These include:

- Lack of general and strategic water plans;
- Even though the Energy Law obligates long term development plans for the distribution and transmission systems, there is still lack of these systems;
- Weak distribution networks in the regions where SHP potential is the highest;[11]
- Low electricity demand in the regions where SHP potential is the highest.[11]

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4.3.7

North Macedonia

Viktor Andonov, former employee of the Ministry of Economy

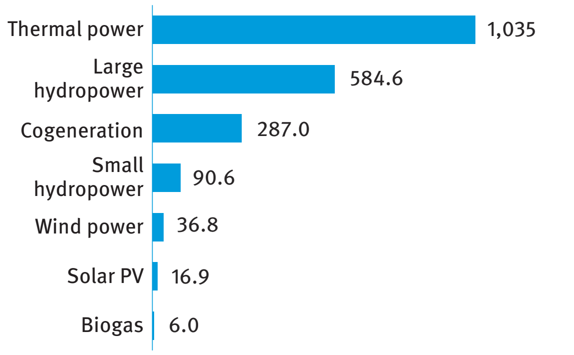
Key facts

Population	2,103,721[1]
Area	25,713 km^2 [1]
Climate	North Macedonia has a transitional climate from Mediterranean to continental. It is warm and dry in summer and autumn, between June and October, with July and August as the warmest months with temperature exceeding 40 °C in some regions of the country. The country is relatively cold with heavy snowfall during winter between December and February. January is the coldest month with an average temperature of 0.3 °C. Average annual temperatures range between approximately 20 °C in July and August to less than 0 °C in January.[2]
Topography	North Macedonia is a land-locked country framed along its borders by mountain ranges and with central valley formed by the Vardar river. The region is seismically active and has been the site of destructive earthquakes in the past. The highest point is Mount Korab at 2,753 metres, the lowest point is Vardar River 50 metres.[3]
Rain pattern	Average annual precipitation varies between 1,700 mm in the western mountainous regions and 500 mm in the eastern area. The wettest months tend to be November and December as well as April and May.[2]
Hydrology	The Vardar is the longest and most important river in North Macedonia, bisecting the country and forming the central valley. It is 388 km long and drains an area of approximately 25,000 km^2. There are also three large lakes – Ohrid, Prespa and Dojran.[3]

Electricity sector overview

Electricity production in North Macedonia is mainly from lignite and large hydropower. In 2016, total installed capacity was 2,057 MW consisting of thermal power plants (1,035 MW), large hydropower (584.6 MW), combined heat and power plants (287 MW), wind (36.8 MW), small hydropower (90.61 MW) and photovoltaic (16.88 MW), thermal power plant on biogas (5.99 MW) (see Figure 1). This represents an increase of 7.53 MW compared to 2015.[4]

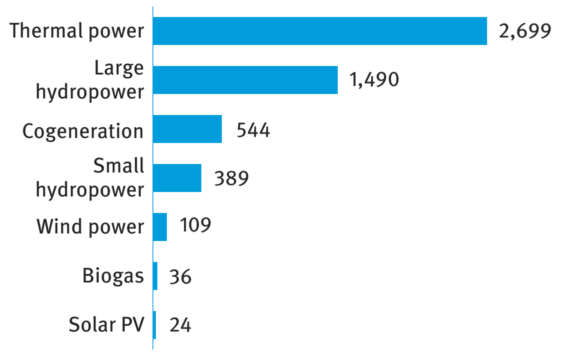
Figure 1.
Installed electricity capacity by source in North Macedonia (MW)



Source: ERC[4]

In 2016 total electricity generation was 5,301 GWh. Thermal power plants contributed 2,699 GWh, large hydropower, 1,490 GWh, wind 109 GWh, combined heat and power plants 554 GWh, small hydropower 389 GWh, photovoltaic 24 GWh, and biogas plants 36 GWh. North Macedonia is also dependent on imports for electricity, largely from Hungary, Romania, Bulgaria, Serbia and Bosnia. In 2016, 29 per cent of electricity generation (2,190 GWh) was imported (see Figure 2).[4]

Figure 2.
Annual electricity generation by source in North Macedonia (GWh)



Source: ERC[4]

The most important renewable resources in North Macedonia are hydropower (large 28 per cent and small 4.4 per cent) and biomass. Wind power will increase in future after the first installed wind park, Bogdanci, with an installed capacity of 36.8 MW in the first phase and a second phase is planned to increase this to 50 MW in the next few years. The Government issued an authorization in 2017 to a private investor to construct a new wind park, Bogoslovec, with installed capacity of 33 MW, to be constructed in the next few years. Generation from solar power plants is also increasing. However, due to the higher investment cost, the Government set a national limit of 18 MW and, taking into account planned constructions, this capacity has already been reached. Several biogas plants are also in operation with a total installed capacity of 5.99 MW. [4]

Large hydropower plants are very important for North Macedonia with several planned projects, such as the hydropower plant Boskov Most (70 MW) and Accumulation Lukovo Pole with Shpp Crn Kamen (160 GWh additional generation in the system). Other plans include Cebren (333 MW), Galishte (200 MW), Gradec (54 MW) and Veles (93.3 MW).[5]

The electrification rate is close to 100 per cent with some remote areas still lacking access to the grid. The distribution grid is operated by EVN Macedonia and, according to the Law on Energy they are responsible for development and upgrading. Grid codes define how consumers can request access to the grid.[6] North Macedonia has successfully implemented the 2nd EU Directive package which includes third party access.[7]

The electricity sector of North Macedonia consists of generation facilities, a transmission system, a distribution system, and final consumers. The main electricity producer in North Macedonia is the state-owned Joint Stock Company Macedonian Power Plants (JSC ELEM) who own 90 per cent of total electricity production. The state-owned Joint Stock Company – Macedonian Transmission System Operator (JSC MEPSO) operates the transmission system while the market operator responsible for distribution is EVN Macedonia, which is 10 per cent state-owned, with the remainder owned privately by EVN AG Austria. Two independent power producers (IPP), CHP TE-TO and CHP KO-GEL, are also present on the electricity market. EVN Macedonia also has small hydropower in their portfolio plants that were constructed between 1927 and 1953 and some of which have been renovated in the last several years. The country's photovoltaic plants are constructed and operated by private domestic and foreign investors.[8]

North Macedonia is a candidate country for the European Union (EU) and a contracting party in the Energy Community. Thus, it is committed to applying the EU Community Acquis in domestic legislation. Accordingly, North Macedonia in the last several years has been working to reform the energy sector to achieve a single regional stable regulatory market framework capable of attracting investment in transmission networks and generation capacity as well as fostering competition and interconnectivity, thus ensuring supply and realizing economies of scale.[14]

The main purpose of implementation of the EU legislation on the internal energy market is the further liberalization of the energy market towards achieving reliable operation of the energy market and creation of conditions for greater competition in the supply of energy to consumers in North Macedonia, as well as promotion of renewable energy sources and improvement of energy efficiency.

At the Summit for the Western Balkan Countries (WB6) in August 2015, North Macedonia signed a joint declaration on the establishment of the regional office for cooperation of the countries of the Western Balkans, agreeing to implement the so-called "energy soft measures", which are divided in four groups: 1) spot market development, 2) cross-border balancing, 3) regional capacity allocation of capacities and 4) cross-cutting measures.

The electricity market in North Macedonia is liberalized and at the present more than 47 per cent of the total consumption is trade between the traders, suppliers and other market players. Although households and some small companies are still part of the regulated market, they are expected to transition to the open market by 2020.[17]

North Macedonia is committed to implementing the reforms in the energy sector and fulfilling the obligations arising from the Treaty establishing the Energy Community. For that purpose, the preparation of a new Energy Law, which include the provisions and obligations arising from the EU Third Energy Package and RES Directive, is ongoing. It is planned to be adopted in the first half of 2018. The adoption of the Energy Law will enable the fulfillment of the energy "soft measures", as well as further liberalization of the energy market towards achieving a secure functioning of the energy market and creating conditions for greater competition in the energy supply of consumers in North Macedonia and promotion of renewable energy sources.[17]

Table 1.
Electricity tariffs for households and small industry in North Macedonia

	Tariff (EUR (US$) per kWh)		
Tariff type	*2014*	*2015*	*2016*
Households	0.0686 (US$ 0.0844)	0.0695 (US$ 0.0856)	0.0692 (US$ 0.0852)
Small industry I tariff system	0.0982 (US$ 0.1208)	0.0995 (US$ 0.1224)	0.1011 (US$ 0.1244)
Small industry II tariff system	0.1400 (US$ 0.1722)	0.1422 (US$ 0.1750)	0.1419 (US$ 0.1746)

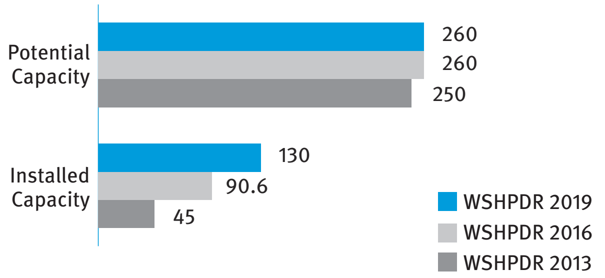
Source: Energy Regulatory Commission[4]

North Macedonia has one of the lowest electricity tariffs for households in the region, and in Europe, ranging between 0.0686 EUR (US$ 0.0844) per kWh to 0.0692 EUR (US$ 0.0852) per kWh in 2016 (see Table 1). The tariffs are set annually by the Energy Regulatory Commission (ERC) and have been increasing incrementally year on year.[4]

Small hydropower sector overview

North Macedonia defines small hydropower as plants with an installed capacity of 10 MW or less. In 2016 small hydropower installed capacity was approximately 90.61 MW (4.4 per cent of the total installed capacity) generating 389 GWh.[4] Potential capacity in the country is estimated at 260 MW. Compared to data from the *World Small Hydropower Development Report (WSHPDR) 2013*, installed capacity has increased by more than 100 per cent in 2016 (as in 2012 most of the plants were still under construction) and reached 130 MW in 2018, indicating a 43 per cent increase compared to the *WSHPDR 2016* (see Figure 3). According to the ERC Report, it was expected in 2018 that an additional 40 MW of small hydropower plants to be operational.[9]

Figure 3.
Small hydropower capacities 2013/2016/2019 in North Macedonia (MW)



Source: ERC,[4] *WSHPDR 2013*,[6] *WSHPDR 2016*[14]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

Small hydropower currently accounts for approximately 15.5 per cent of the total installed hydropower capacity and approximately 4.41 per cent of the country's total installed capacity. However, North Macedonia has a significant potential for small hydropower development with more than 400 identified sites throughout the country which could potentially meet up to 16 per cent of the country's current electricity demand. The central study on small hydropower potential in North Macedonia is the Feasibility Study for Small And Mini-hydropower produced in 1982 by the Faculty of Mechanical Engineering, Skopje University. The potential for the installed capacity in the study was approximately 250 MW with the individual capacities ranging from 50 kW to 5,000 kW. [10]

Small hydropower plants in North Macedonia are constructed according the Law on Waters and the Law on Concessions and Public Private Partnership.[11] Between 2007 and 2011 the Ministry of Economy of the Republic of North Macedonia conducted five tendering procedures for granting water concessions for the electricity production from small hydropower plants. The Ministry of Economy signed 66 concession agreements with 23 concessioners, both foreign and domestic, with a combined installed capacity of 60 MW and estimated annual production of 240 GWh. The level of investment is expected to be between 120 and 150 million EUR (US$ 150 and 200 million).

From 2011 the Ministry of Environment and Physical Planning became responsible for granting the water concessions for construction of small hydropower plants. In 2014 they conducted the sixth procedure for granting the water concessions for the electricity production from small hydropower plants and in 2015 they signed the concession agreements for construction of 19 small hydropower plants with total installed capacity of 23 MW.[14] In the period of 2016–2018 additional concession agreements were signed for the construction of 31 small hydropower plants with installed capacity of 50 MW. The concession agreements are signed for a period of 23 years from which three years are given for obtaining all the necessary licences and the construction of a plant. The concessionaires will produce electricity for a period of 20 years with guaranteed purchases by the market operator.

With these signed agreements for concessions, alongside public-private partnerships, it is estimated that North Macedonia will have approximately 110 newly constructed small hydropower plants with an approximate installed capacity of 130 MW by 2020.

The Government of North Macedonia has supported the construction of small hydropower plants as a renewable energy source introducing feed-in tariffs (FITs) in 2007. The tariff is a declining tariff based on the monthly electricity production (see Table 2). The Government has also signed several direct agreements with the European Bank for Reconstruction and Development (EBRD) for supporting their loan agreements with several concessionaires. This possibility is given to all investors who signed the agreements and are seeking loans from different financial institutions.[11]

Table 2.
Feed-in tariffs in North Macedonia for small hydropower plants by capacity

Produced electricity per month (kWh)	*FIT (EUR (US$) per kWh)*
≤ 85,000	0.120 (US$ 0.16)
> 85,000 and ≤ 170,000 kWh	0.080 (US$ 0.11)
> 170,000 and ≤ 350,000 kWh	0.060 (US$ 0.06)
> 350,000 and ≤ 700,000 kWh	0.050 (US$ 0.07)
> 700,000 kWh	0.045 (US$ 0.06)

Source: Decree for Feed-in Tariffs[12]

Renewable energy policy

Greater utilization of the renewable energy sources (RES) and improvement of the energy efficiency (EE) is one of the main strategic goals in the energy sector for the Government of the Republic of North Macedonia.[16, 18, 19]

According to obligations from the Energy Community, the target for Republic of North Macedonia is 28 per cent by 2020.[5] However, some consider this to be too high and based on inaccurate data of the biomass potential. A survey by the State Statistical Office on energy consumption in households was finished and the Government adopted a revised RES Action plan based on the new data.[15] According to the revised RES Action Plan, the percentage share of RES in 2020 should be 23.9 per cent, and in 2025 should be 25 per cent. This percentage should be achieved through the construction of new RES plants, as well as reinforced energy efficiency measures in accordance with the RES Strategy and Energy Efficiency Strategy.[13]

According to the Second Progress Report on RES, the share of RES in 2014 was 19.7 per cent and in 2015 was 19.9 per cent. The current share of renewable energy sources of total final energy consumption is 18.2 per cent. In order to align its policies with the EU, the Government has made efforts to promote the electricity production from the renewable energy sources. Incentives are provided through FITs for the licensed producers of electricity with guaranteed purchasing of the total amount of electricity produced for the period of using this preferential tariff. Renewable energy plants also have priority in dispatching by the market operator. The eligibility for application of FIT for small hydropower plants is an installed capacity up to 10 MW per plant and there is no national limitation on the number of small hydropower plants.[11]

The FIT proposed for wind power is for plants up to 50 MW, while there is a total national installed capacity limit of 150 MW. For co-generation plants using biogas and biomass the national limit is set at 10 MW. This is primarily due to the relatively small potential of these renewable sources. For photovoltaic plants the national limit under the current FIT is 18 MW with 4 MW assigned to plants with a capacity lower than 50 kW and 14 MW assigned to plants up to 1 MW.

The Government sets the FIT for all types of renewable energy sources except for geothermal energy (see Table 3).[11]

Table 3.
Feed-in tariffs in North Macedonia

Technology	*Max plant size*	*FIT (EUR (US$) per kWh)*	*Period (years)*	*Max. national capacity*
Wind (onshore)	50 MW	0.089 (0.119)	20	150 MW
Solar PV (< 0.05 MW)	1 MW	0.160 (0.213)	15	4 MW
Solar PV (> 0.05 MW)	1 MW	0.120 (0.160)	15	14 MW
Biomass	3 MW	0.150 (0.200)	15	10 MW
Biogas	-	0.180 (0.240)	15	6 MW

Source: Decree for Feed-in Tariffs[11]

In accordance with the 2017 Sustainability Charter signed within the Western Balkans Summit (WB6), the Republic of North Macedonia has committed itself to introducing market-oriented support mechanisms for the promotion of RES (auctions and feed-in premiums), which would be acquired in a competitive and transparent manner through the implementation of a public announcement for charging the amount of the feed-in premium (leaving the current mechanism, i.e. FITs). The new Energy Law shall prescribe the market-oriented support mechanisms for the promotion of RES and the simplified procedures for construction of new RES plants.

Barriers to small hydropower development

Some of the most critical issues concerning the development of small hydropower plants in the future are:

- The need for accurate hydrological data for an extended time period because previous estimates of the capacity potential have been criticized for overestimating the volume of water at some sites;
- Connection to the distribution grid, most of the potential small hydropower locations are in rural areas with either no connection or no stable, quality network;
- Investment cost of grid connection is often very high. In the last several years a number of legislations and sub-legislations were amended in order to streamline the procedures for obtaining the construction permit.
- Establishment of a single authority for all the procedures, licences and permits in order to reduce the time needed to realize these projects.[14]

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4.3.8

Portugal

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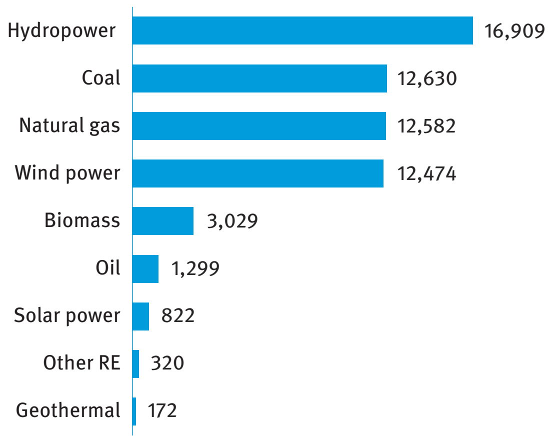
Key facts

Population	10,291,027[1]
Area	92,225.6 km^2 [1]
Climate	Portugal is characterized by a temperate climate with hot and dry summers between June and August in the south, and dry and mild summers in the north. Average annual temperature varies from 7 °C in the northern regions of the country and 18 °C in the southern regions.[1]
Topography	The centre and north of Portugal are mountainous regions with several mountain chains reaching as high as 1,500 to 1,900 metres. In the south, plains are characteristic, although some high mountains can also be found. At 1,993 metres, Serra de Estrela is the highest point in mainland Portugal. However, the summit of Mount Pico on the Azores is higher at 2,351 metres.[3]
Rain pattern	Total annual precipitation ranges between 2,400 mm and 2,800 mm in the north-western coastal mountains and 400 mm in the south. In the south, monthly variations are more intense, and 80 per cent of precipitation tends to occur during the wet season, which is typically from October to March, with November and December generally the wettest months. July and August are the hottest and driest months.[3]
Hydrology	Transboundary river basins in Portugal represent around 64 per cent of the country's territory, with the largest rivers being the Tagus, Douro and Guadiana; the main rivers exclusively within Portugal's territory are the Mondego, Vouga and Sado. In 2005, the country's total water dissipation per inhabitant was 6,546 m^3/year. River flows have high seasonal variations due to precipitation patterns, mainly in the south of the country, and hydropower dam operation occurs mainly in the north.[3]

Electricity sector overview

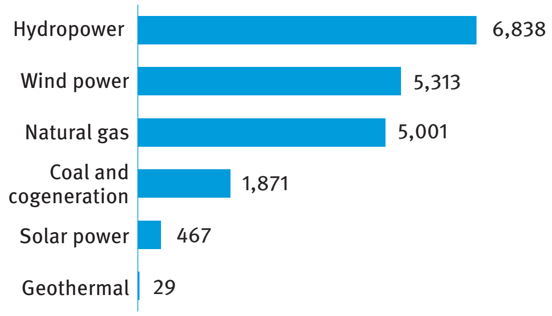
In 2016, total electricity generation in Portugal was 60,237 GWh, distributed by source according to Figure 1.[13] In the same year, the installed capacity was 19,519 MW, including 6,838 MW of hydropower, 5,313 MW of wind power, 5,001 MW of gas, 1,871 MW of coal and cogeneration plants, 467 MW of solar and 29 MW of geothermal power (Figure 2).

Figure 1.
Annual electricity generation by source in Portugal (GWh)



Source: Direção Geral de Energia e Geologia[13]

Figure 2.
Installed electricity capacity by source in Portugal (MW)



Source: Direção Geral de Energia e Geologia[13]

In 2016, the rate of energy dependence was 74.9 per cent, reflecting the lack of fossil fuels availability in the country. Portugal imports most of its required energy.[13] This dependence rate has been reduced since 2005, mostly as a result of increasing hydropower installed capacity and production.

The electrification rate in the country is close to 100 per cent and the overall energy mix is strongly influenced by the transport sector, which represents 36 per cent of the primary energy consumption and 73 per cent of the total oil demand for energy purposes.[10]

The privatization process of the energy sector has recently concluded, partly as a result of the bailout process enforced between 2011 and 2014. Accordingly, the main energy company Energias de Portugal (EDP) became completely independent from the state, with the China Three Gorges Corporation becoming its main shareholder with 21.[35] per cent control. In 2014, the privatization of the electricity grid infrastructure was also concluded, with the State Grid of China becoming the main shareholder with a 25 per cent share. EDP remains the country's main electricity distributor, although the energy market is being gradually liberalized.

On the Portugal mainland, transmission is handled by a single company, Rede Eléctrica Nacional (REN), while most of the distribution networks are handled by EDP Distribuição along with several low-voltage electricity distribution operators. Electricity suppliers are responsible for managing the relations with the end consumers, including billing. In Portugal, mainland electricity can be sold on a liberalized market through free suppliers and on a regulated market through the last resort supplier. In 1998, the Portuguese and Spanish administrations began building the shared Iberian Electricity Market (MIBEL).

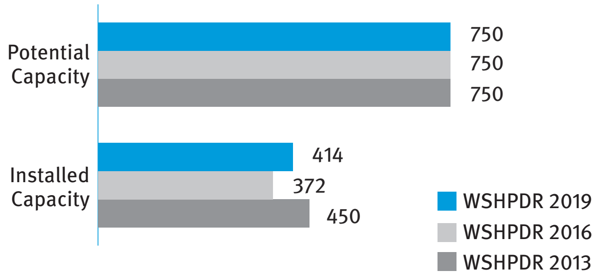
Portugal's energy market is regulated by the Energy Services Regulatory Authority (ERSE), the sectorial regulator for gas and electricity and an independent legal entity of public law, financially and administratively autonomous according to Decree-Law No. 97/2002 and updated with Decree-Law No. 84/2013. The process of market liberalization is therefore not complete, as there are still some regulated tariffs in place. Though full market liberalization has been postponed since the initial date was fixed, it is expected to be completed in the near future; the impacts on the energy market are yet to be evaluated along with the effects associated with the privatization process.

Historical tariffs are well documented but have been subject to multiple tax-related changes, some of which have had a relevant impact on costs to consumers. Consumer prices have varied over the years. Although some tariffs have regional differences, they are generally market driven. Average costs in the second half of 2014 were EUR 0.223 (US$ 0.297) per kWh and EUR 0.119 (US$ 0.159) per kWh for residential and industrial consumers, respectively.[1]

Small hydropower sector overview

In Portugal, small hydropower (SHP) is defined as plants with a capacity of 10 MW or less. In 2018, installed SHP capacity was 414 MW.[14] However, there are no accurate or complete studies for SHP potential.[1] Nonetheless, the country's National Renewable Energy Action Plan (NREAP) is aiming for a total of 750 MW capacity from 250 plants by 2020, indicating that, at minimum, this potential exists.[15] Current capacity constitutes approximately 50 per cent of this target.

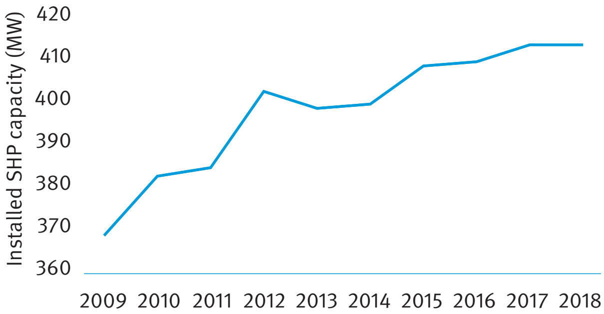
Figure 3.
Small hydropower capacities 2013/2016/2019 in Portugal (MW)



Source: *WSHPDR 2013*,[8] *WSHPDR 2016*,[16] Direcção Geral de Energia e Geologia[14]

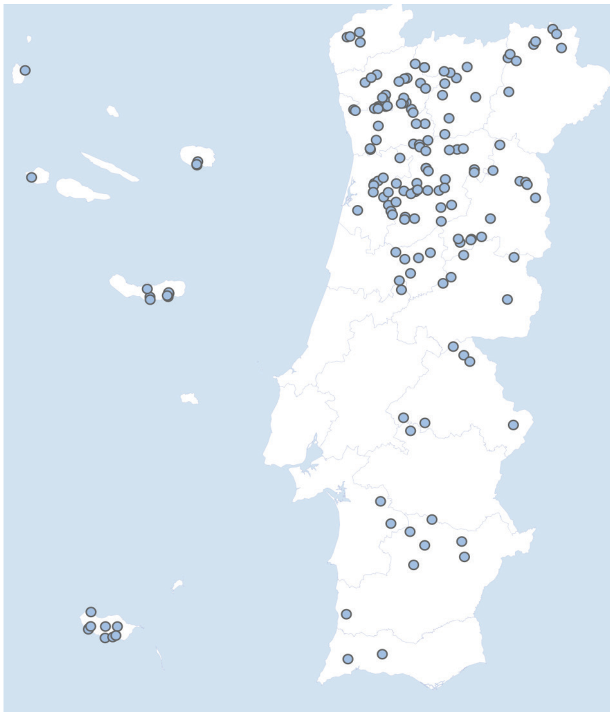
Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

Figure 4.
Small hydropower capacities 2009-2018 in Portugal (MW)



Source: Direcção Geral de Energia e Geologia[14]

Figure 5.
Location of small hydropower plants in Portugal



Source: Energias Endógenas de Portugal[6]

Since 2007, the National Plan for Dams with High Hydropower Potential has been underway, defining the construction of ten new large dams, three of which have already been cut. Thus, this plan is only half complete and its continuation may depend on the Government's options, international energy prices and limits placed on energy exports to European countries related to energy market constraints, which represent real obstacles in pursuing an increase in large hydropower capacity.

Renewable energy policy

A key challenge for the Portuguese energy sector is to reduce energy dependence, a goal which can only be achieved by developing renewable energy sources. Currently, renewable energy sources constitute a 27 per cent share of the energy sector and a 58 per cent share of the electricity sector.9 According to a study developed by Deloitte for the Renewable Energy Association (APREN), although future renewable energy growth is predicted to be below the European Union and average global expected growth, a further 7,100 MW of installed power is expected from the renewable sources by 2030.[10]

Current energy policy is built on two major pillars: sustainability and economic rationality on the basis of energy efficiency; and incorporating endogenous renewable sources and reducing costs. Goals outlined in the National Plan of Action for Energy Efficiency, National Action Plan for Renewable Energies and the Program of Energy Efficiency in the administration are to:

- Reduce greenhouse gases in a sustainable manner;
- Diversify primary energy sources;
- Increase energy efficiency;
- Contribute towards increased economic competitiveness.[11,12]

Legislation on small hydropower

There is no regulation published on establishing the residual flow. Yet, there are indications that the ecological flow in Portugal should be, on average, 5-10 per cent of the modular flow. Also, this flow should be variable during the year to enable a better adjustment to the differences in the natural hydrological regime and to the spawning seasons. The residual flow would be the sum of the ecological flow with the flow necessary for the existing uses such as irrigation and water supply.[9]

In Portugal, the support scheme in place for SHP is its feed-in tariff (FIT). The Decree-Law No. 225/2007 indicates an average reference FIT of 7.5-7.7 EUR/kWh (8.5-8.7 US$/kWh), with a limit set to the first 52 GWh/MW or up to 20 years, whichever is reached first. It could also be increased to 25 years in exceptional cases. In 2010, a new tariff was defined by the Decree-Law No. 126/2010 specifying for the public tender launched in that year a 9.5 EUR/kWh (10.8 US$/kWh) tariff for up to 25 years.[9]

Barriers to small hydropower development

In general, technical capacity is available in the country, while state-of-the-art information systems and social awareness of environmental issues support the growth of the renewable energy sector. Furthermore, the national electricity grid infrastructure is of no major concern.

Portugal is in a slow stage of development of its SHP sector with only a few power plants being developed in the last decade. Major barriers include:

- A lengthy, costly and unpredictable licensing procedure; the licensing procedure for an SHP plant can take, on average, between three and 11 years;
- Legal constraints, particularly in regard to more stringent environmental requirements, such as the Water Framework Directive, can lead to a limitation of the technical characteristics and potentially the profitability of a project;
- Inadequate support mechanisms, for instance, a reduction in the value of the FIT in 2005 led to a significant decrease in the number of new SHP plants;
- Limitations on energy exports are an obstacle to the increase of renewable energy sources. However, SHP is socially preferred over large dam construction, as environmental and economic impacts are reduced.

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4.3.9

Serbia

International Center on Small Hydro Power (ICSHP); Jovan Despotović, Serbian IHP Committee

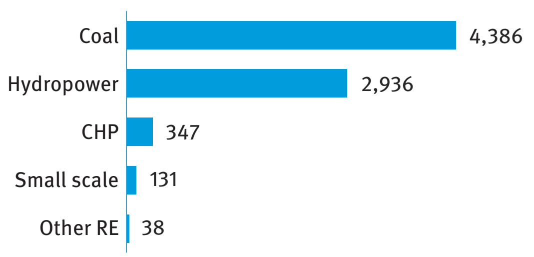
Key facts

Population	7,022,268[1]
Area	88,499 km[2]
Climate	In Serbia, the climate is predominantly continental with cold, dry winters and warm, humid summers. In the capital city of Belgrade, the difference between average January and July temperatures is 22 °C. In the Vojvodina, July temperatures average 22 °C, while January temperatures fluctuate around -1 °C. There are certain variations in the climate depending on the elevation, proximity to the sea and exposure to wind. Thus, in the mountain areas summer temperatures are notably cooler, averaging 18 °C.[2]
Topography	Serbia is a landlocked country. The northern Vojvodina region is characterized by plains lying at elevations between 60 and 100 metres above seas level. In the west, the plains are interrupted by the Fruška Gora hills, with their highest point reaching 540 metres. The central part of the country is covered in hills and high mountains, belonging to the Dinaric Alps, the Carpathians and the Rhodope Mountains. The granite ridge of the Kopaonik Mountains in the south-west reaches 2,017 metres, the Balkan Mountains bordering Bulgaria reach the elevation of more than 2,100 metres and the summits of the Šumadija hills range between 600 and 1,100 metres. The highest point in the country is Đeravica (2,656 metres) in the Prokletije Mountains.[2]
Rain pattern	Precipitation depends on elevation and exposure and ranges between 560 and 1,900 mm. The Vojvodina region receives the lowest amount of rainfall at approximately 500 to 600 mm per year. Most precipitation falls during the warmer half of the year, with the majority occurring in May or June and October. In the winter, there are usually 40 days of snow cover in the northern lowlands and 120 days in the mountains.[2]
Hydrology	Serbia belongs primarily to the basin of the Danube, which flows into the Black Sea. The Tisa River is the largest tributary of the Danube in the Vojvodina region, while the Sava is the major western tributary of the Danube. The Morava is the largest river that flows entirely within the territory of Serbia and draining two-fifths of the country's territory. It is 290 kilometres long and flows northwards into the Danube. In the south-east, flow the Vardar River draining into the Aegean Sea and its tributaries.[2]

Electricity sector overview

In 2017, the installed capacity of Serbia was 7,838 MW, of which 56 per cent was from coal- and natural gas-fired power plants, 38 per cent from hydropower plants, 4 per cent from combined heat and power (CHP) plants and approximately 2 per cent from other renewable energy sources and small-scale power plants of all types (Figure 1).[3]

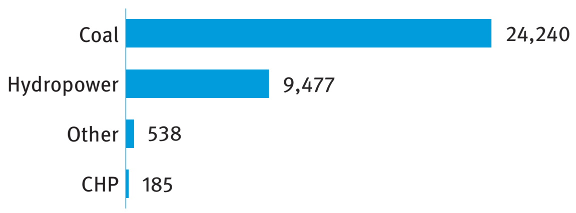
Figure 1.
Installed electricity capacity by source in Serbia (MW)



Source: AERS[3]

Overall electricity generation in 2017 was 34,441 GWh, which was 6 per cent less than in 2016. Thermal power accounted for 70 per cent, hydropower for almost 28 per cent, other power plants for less than 2 per cent and CHP 0.5 per cent (Figure 2).[3] In 2017, Serbia imported approximately 3,397 GWh of electricity and exported approximately 2,061 GWh.[3] Access to electricity in Serbia stands at 100 per cent, both in urban and rural areas.[4]

Figure 2.
Annual electricity generation by source in Serbia (GWh)



Source: AERS[3]

The development of the electricity sector of Serbia has been influenced by several factors, such as difficulties with economic development and major political changes, which has led to frequent changes in the country's institutional and regulatory frameworks. Moreover, the legal framework has been subject to continuous improvement and harmonization with the legislation of the European Union.[5] The important steps in this relation were the implementation of the Water Framework Directive (Directive of European Parliament and of the Council 2000/60/EC) and the ratification of the treaty establishing the Energy Community, under which Serbia agreed to adopt and carry out the plan for implementing Directive 2001/77/EC to promote of electricity produced from renewable energy sources, to enforce a set of regulations on reducing greenhouse gas emissions and to accede the International Renewable Energy Agency (IRENA).[5,6,7] In order to facilitate the functioning of a regional and pan-European electricity market, Serbia's electricity network requires better integration with neighbouring countries. Under the Trans-Balkan Electricity Corridor project, which is planned to connect Romania, Serbia, Bosnia and Herzegovina, Montenegro and Italy, the initial step of constructing a 400 kV overhead transmission line connecting Romania and Serbia was completed in 2017.[8]

Serbia's electricity sector was restructured following the adoption of the Energy Law. Currently, the sector is dominated by the companies PE Elektroprivreda Srbije (EPS) and JP Elektromreža Srbija (EMS), although there are also a number of private companies involved in the electricity wholesale market, including imports and exports. EMS operates the transmission system, transmitting electricity and organizing the electricity market, while EPS is in charge of electricity generation, distribution and retail through its subsidiary companies EPS Distribution and EPS Supply.[9] Since 2016, EMS has operated as a non-public joint-stock company with 100 per cent state ownership.[10] Currently, EPS is undergoing a process of restructuring and is working on the modernization of its capacities and increasing its share of renewable energy sources. In its efforts to improve the performance of the EPS, the Government receives the technical assistance of the World Bank, which focuses on strengthening the company's corporate governance, risk management and business planning. In 2018, the Government announced that EPS would be transformed into a joint-stock company in 2020, which is expected to improve its viability.[11] The electricity market in Serbia was almost completely liberalized following the introduction of the electricity market/power exchange in February 2016.

Under the Energy Law, the Energy Efficiency Agency (EEA) and the Energy Agency of the Republic of Serbia (AERS) were established. The aim of the EEA is to promote energy efficiency, rational use of energy resources and the development of renewable energy sources and to establish the energy efficiency fund. The AERS is the regulatory body directing the energy market's development based on the principles of non-discrimination and competition, monitoring the implementation of regulations, harmonizing the activities of energy entities, issuing licences for conducting energy activities and ensuring a regular supply of energy and services to customers.[12]

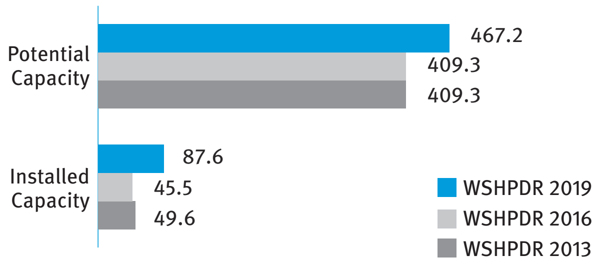
As of 1 January 2018, electricity tariffs ranged between 0.035 EUR/kWh (0.041 US$/kWh) to 0.056 EUR/kWh (0.065 US$/kWh) depending on the tariff.[13]

Small hydropower sector overview

Small hydropower (SHP) is defined in Serbia as hydropower plants with capacity up to 30 MW. This definition was introduced in January 2013 following the adoption of the Decree on Incentive Measures for Privileged Electric Power Producers.[14] Until December 2012, the term applied to all hydropower plants with the installed capacity up to 10 MW regardless of their type (reservoir or run-of-river plants).[15]

As of October 2018, the installed capacity of SHP plants in Serbia was 87.6 MW, while the potential was estimated at approximately 467 MW, indicating that 19 per cent has been developed.[16,17] Compared to the *World Small Hydropower Development Report* (*WSHPDR*) *2016*, installed capacity almost doubled due to the commissioning of new plants, while potential increased by some 14 per cent due to access to more accurate data (Figure 3).

Figure 3.
Small hydropower capacities 2013/2016/2019 in Serbia (MW)



Source: *WSHPDR 2016*,[5] MRE,[16] MRE,[17] *WSHPDR 2013*[18]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

Small hydropower has a long history in Serbia. The first SHP plant, Pod Gradom on the Đetinja River, was installed in 1900 based on Nikola Tesla's principle of a three-phase alternating current. Between 1900 and 1940, 26 plants were built.[19] Currently, there are 131 SHP plants operating in Serbia with the status of a privileged power producer or a temporary privileged power producer. These plants range in capacity from 10.7 kW to 7 MW. Over 70 of these plants were commissioned after 2016.[16]

In the late 1980s, a detailed study of the SHP potential of small rivers of Serbia was carried out. Based on the study, the *Survey of Small Hydropower Plants in the Republic of Serbia* (1987) and the *Survey of Small Hydropower Plants in Vojvodina* (1989) were drafted. The lists from the surveys include 856 suitable locations in Central Serbia and 13 in Vojvodina.[19] The combined capacity of potential SHP sites with capacity up to 10 MW is approximately 467 MW.[17] The greatest SHP potential is concentrated in the mountainous areas in the west and the south, while in the northern, flatter part of the country the potential is somewhat lower. However, it should be noted that these surveys did not take into account restrictions related to the water management, water supply, environmental protection and cultural heritage.[20] In order to foster the development of SHP in the country, a project for the preparation of a new cadastre of potential sites was launched in December 2016 and is planned to be completed within two years.[21]

The Government of Serbia supports initiatives aimed at increasing the hydropower capacity, focusing on the modernization and upgrading of existing plants, the construction of new facilities and encouraging the development of the SHP sector.[5] According to the Energy Sector Development Strategy, an additional 208 MW of new SHP capacity will be introduced by 2020, 300 MW by 2025 and 400 MW by 2030 (Table 1).[22]

Renewable energy policy

In 2014, a new Energy Law of the Republic of Serbia was adopted, harmonizing the country's legislation with the Third Energy Legislation Package of the European Union. This law outlines the aim to create economic, commercial and financial conditions for generating energy from renewable energy sources and to promote environmental protection in all energy-related areas. The law regulates issues related to SHP, including all types of licences and permits and their privileged position in the market compared to other energy producers. It also implies the right to subsidies (tax, tariff and other subsidies), feed-in tariffs (FITs) as well as such incentives as the obligation of the public supplier to purchase electricity from the producer.[23]

Table 1.
Projection of the construction of power plants using renewable energy sources

	Planned installed capacity (MW)		
Renewable energy source	*2020*	*2025*	*2030*
Wind power	500	500	600
Hydropower (<10 MW)	208	300	400
Hydropower (>10 MW)	250	300	350
Biomass	100	150	200
Solar power	10	100	200
Biogas	43	60	80
Geothermal power	1	3	5
Total	**1,112**	**1,423**	**1,835**

Source: MME[22]

The Energy Sector Development Strategy adopted in 2016 encourages investment in renewable energy technologies and sets goals for utilizing renewable energy sources and their implementation by 2020, 2025 and 2030. The total installed capacity of new renewable energy plants planned to be introduced will increase progressively from 1,112 MW in 2020 to 1,413 MW in 2025 and 1,835 MW in 2030 (Table 1).[22]

Other legal acts specifically regulating the functioning of SHP include:

- Decree on the Requirements for Obtaining the Status of a Privileged Electric Power Producer and the Criteria for Assessing the Fulfilment of these Requirements (2009);
- Model Agreement on Purchasing Electric Power from Privileged Producers (2009);
- Decree on Incentive Measures for Privileged Electric Power Producers (2013).[5]

The 2010-2020 Spatial Plan of the Republic of Serbia governs the spatial development in the country. It provides an overview of the available hydropower potential and deals with sites suitable for SHP development, taking into account the available cadastre of potential sites and also suggesting that such locations should be protected against unplanned usage.[5,24]

The Decree on Incentive Measures for Privileged Electric Power Producers determined privileged purchase prices of electricity from SHP plants (Table 2).[25] The FIT system expired at the end of 2018. The Ministry of Mining and Energy announced that the system would be replaced by an auction-based model.[26]

Table 2.
Feed-in tariffs for small hydropower

Categories of plants	*Installed power (MW)*	*Feed-in tariff (EUR/kWh (US$/kWh))*
Newly built facilities	< 0.2 MW	0.126 (0.15)
Newly built facilities	from 0.2 MW to 0.5 MW	0.139-0.067 (0.16-0.08)
Newly built facilities	from 0.5 MW to 1 MW	0.106 (0.12)
Newly built facilities	From 1 MW to 10 MW	0.109-0.003 (0.13-0.004)
Existing infrastructure	<30 MW	0.060 (0.069)

Source: MME[25]

Barriers to small hydropower development

The current legislation and policies aim to promote more intensive development of SHP, however, a number of factors hindering the development still exist. These include:

- Complicated permit issuing procedures;
- High initial investment requirements (costs of preliminary and main project drafting);
- Limited funds for investing in projects;
- Low awareness of the advantages of SHP, both among professionals and the general public;
- Insufficient knowledge of existing technologies and economic and ecological indicators;
- Payback time estimation.[5,19]

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4.3.10

Slovenia

Aleksandra Aubreht and Dr. Saso Santl, Institute for Water of the Republic of Slovenia

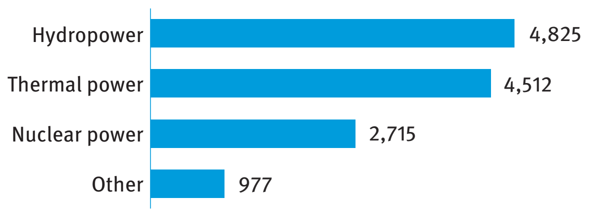
Key facts

Population	2,065,890
Area	20,271 km^2
Climate	The climate is continental with cold winters and warm summers. However, the coastal areas enjoy a sub-Mediterranean climate. The average temperatures are -2 °C in January and 21 °C in July.[5]
Topography	The topography is predominantly elevated. Outside the coastal area, the terrain largely consists of karstic plateaus and ridges, the alpine area with mountain and hill chains, basins and valleys and also river lowlands in the south-east. The highest Alpine peak is Triglav at 2,864 metres above sea level.[8]
Rain pattern	The average rainfall is 1,000 mm at the coast, up to 3,500 mm in the western areas of the Alps, 800 in the south-east and 1,400 mm in central Slovenia. Snowfall is plentiful in winter months (December – February).[5]
Hydrology	Slovenia exhibits an above average precipitation. The average measured specific runoff in Slovenia is 27 l/sec/km^2, which is equivalent to 588 m^3/sec of total runoff from the country's territory. The Mura and the Drava transit streams, flowing from Austria, have a common average annual runoff of 418 m^3/sec, and the total average runoff from the territory of Slovenia amounts to 1,006 m^3/sec.[4]

Electricity sector overview

In 2016, electricity generation in Slovenia amounted to 13,029 GWh. Thus, electricity generation increased by 1.3 TWh in comparison to 2015 as a result of a higher generation by hydroelectric power plants, thermal power plants and one nuclear power plant. However, compared to 2014, electricity generation in 2016 decreased by more than 4 TWh, which was mainly due to a significant reduction of nuclear power generation.[29] The largest share of electricity production in Slovenia was contributed by the hydropower plants, which accounted for 37 per cent of all electricity generated, followed by the thermal power plants with 35 per cent and the nuclear power plant with 21 per cent.[3] The remaining 7 per cent came from other energy sources, including cogeneration from the fossil fuels and biomass, small hydropower, solar energy, wind and biogas (Figure 1). The share of electricity generated by the hydropower plants and plants using other renewable energy sources (RES) annually varies, depending on the hydrological and other conditions and the investments in new generating facilities using renewable energy sources (RES).[3]

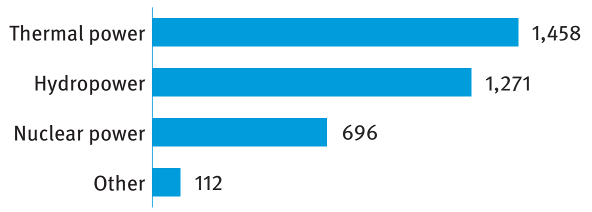
Figure 1.
Annual electricity generation by source in Slovenia (GWh)



Source: Energy Agency[3]

The total installed capacity of Slovenia in 2016 was 3,537 MW (Figure 2). The largest share of installed capacity was contributed by the thermal power plants with 1,458 MW, followed by the hydropower plants with 1,271 MW and the nuclear power plant with 696 MW (half of which is under the ownership of Croatia). The remaining share of the installed capacity was from other energy sources, including biomass, solar, wind and geothermal power.[3]

Figure 2.
Installed electricity capacity by source in Slovenia (MW)



Source: Energy Agency[3]

The electricity and energy sector of Slovenia is regulated by the Energy Act, which was last amended in 2015.[25] The reform was needed to implement directives of the European Union (EU) that were adopted after the previous law had been enacted in 2007. It also aimed to bring the law into compliance with the decisions of the Constitutional Court of Slovenia, which had declared the previous law unconstitutional regarding certain aspects of how network charges are determined and calculated. The current law clarifies the principles of energy policy, energy market operation rules and manners, the forms to provide public services in the energy sector, the principles and measures to achieve a secure energy supply, improving energy efficiency and energy saving, as well as increasing the use of energy generated from RES. In Slovenia, the Energy Agency is the market regulator responsible for ensuring the transparency of market operations, determination of methodologies for the energy sector, issuing guarantees of the origin of electrical energy and commercial green certificates for the production of electricity from RES. Borzen is the market organizer tasked with promoting the development of the Slovenian electricity market and market mechanisms in accordance with EU guidelines. It also contributes to the proper functioning of the Slovenian power system, the alignment of Slovenian and EU legislation and integration of the Slovenian electricity market into the integrated European electricity market.[29]

In Slovenia, large electricity producers as well as the transmission and distribution systems are owned by the state. The activities of electricity transmission and distribution are mandatory national public services and are carried out by the electricity system operators, which are also owned by the state. Small electricity producers (up to 10 MW), distribution companies and energy market suppliers can be publicly, privately or mixed owned. The total length of the transmission electric network in Slovenia is 2,852 kilometres. It connects major producers, big consumers and neighbouring countries Austria, Croatia and Italy. The total length of the distribution network is approximately 65,000 kilometres (70 per cent is low voltage network), which also includes street lighting, and by which the Slovenian territory is efficiently covered by also reaching existing small producers.[29]

Total electricity consumption in Slovenia in 2016 amounted to 14,173 GWh, with domestic production having covered 88 per cent of the demand.[3] At the end of 2016, a total of 945,422 electricity consumers were connected to the power system. In comparison to 2015, the number of consumers increased by 4,653, or 0.5 per cent. The number of household consumers with two-tariff metering consumption in 2016 increased by 1.4 per cent, while the number of household consumers with single tariff metering decreased by 1.5 per cent.[3] The electrification rate in the country is 100 per cent. No significant seasonal fluctuations in monthly consumption have been observed.

In 2016, 1,003.5 GWh of electricity was generated by the plants included in the support scheme, which is aimed at promoting the production of electricity from RES and the cogeneration of combined heat and power (CHP). Thus, compared to 2015, electricity production by plants included in the support scheme increased by 2.3 per cent, and compared to 2014, by 10.8 per cent. This increase was a consequence of favourable hydrological conditions and the resultant increase in production from hydropower plants, as well as increased generation by biogas- and biomass-fired plants. Despite the absolute increase in electricity production, the share of these plants in the total electricity production of Slovenia decreased by 0.7 percentage points (from 8.4 per cent in 2015 to 7.7 per cent in 2016) due to higher total electricity generation in 2016 compared to 2015.[3]

Considering the implementation of the measures for efficient energy use, it is expected that the overall energy consumption in Slovenia by 2020 will increase by less than 5 per cent and gross electricity consumption will increase by less than 10 per cent.[6] The major challenges hindering the growth of electricity production from RES, especially from hydropower, is the lack of proper harmonization and balance with the country's environmental and nature preservation objectives. Addressing this challenge requires closer collaboration between relevant authorities and harmonized strategic decision-making. The document Energy Concept of Slovenia, which is intended to define and harmonize Slovenia's strategic energy development is currently being prepared and is planned to be adopted in 2018. The main objectives of the document are significant reduction of greenhouse gas emissions in the field of energy production (at least by 80 per cent by 2055) with consideration of sustainability and climate acceptability, supply reliability and competitiveness.[16]

The electricity market of Slovenia was opened on 1 July 2007. As such, electricity prices for general industrial and household consumers now depend on the wholesale market in Slovenia and in the EU.[17] The average electricity price for household consumers in Slovenia in the fourth quarter of 2017 was 0.15 EUR/kWh (0.18 US$/kWh). The average electricity price without value added tax for the non-household consumers was 0.08 EUR/kWh (0.09 US$/kWh).[21] The international comparison of electricity prices for the first half of 2017 shows that, in Slovenia, prices for the household consumers (2,500-5,000 kWh of annual consumption) with taxes represented 79 per cent of the EU-28 average and for the non-household consumers without value added taxes (500-2,000 MWh of annual consumption) 69 per cent of the EU-28 average.[22]

EU and Slovenian regulations support electricity production from RES and also consider high efficiency cogeneration, however support is only granted to plants whose electricity generation costs exceed the price of electricity in the open electricity market. By the end of 2017, there were 89 hydropower plants included in the scheme. The total installed capacity of these plants was approximately 22 MW.[26] It is expected, that in 2030, hydropower will account for more than 80 per cent of the electricity produced from the RES, reaching 5,581 GWh, which implies an 18 per cent increase compared to 2015.[19]

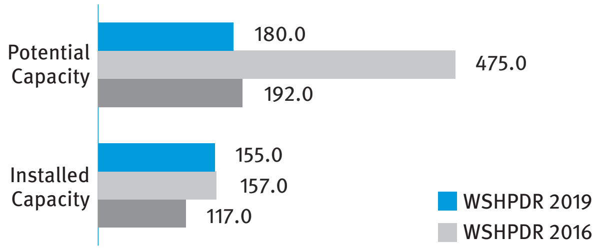
Small hydropower sector overview

This report is using the definition of small hydropower (SHP) as hydropower plants of up to 10 MW. However, there are different definitions of SHP in Slovenia. From the water management perspective, SHP is defined as a hydropower plant with an installed capacity of less than 10 MW. From the RES electricity generation perspective, there are four categories:

- Micro: less than 50 kW;
- Small: between 50 kW and 1 MW;
- Medium: between 1 and 10 MW;
- Large: more than 10 MW.[27]

The installed capacity of SHP plants in Slovenia in 2016 was 155 MW.[30] According to the overall estimations, there are around 180 MW of SHP potential, which can be exploited technically and economically efficiently.[12] However, taking into consideration the residual flow (ecological flow) and other environmental, legal and spatial limitations, the exploitable potential of SHP is more limited. Compared to the results of the *World Small Hydropower Development Report (WSHPDR) 2016*, the installed capacity decreased only slightly, by approximately 1 per cent, whereas the potential decreased by approximately 60 per cent due to access to a more accurate estimate of the exploitable potential (Figure 3).

Figure 3.
Small hydropower capacities 2013/2016/2019 in Slovenia (MW)



Source: HSE Skupina,[12] *WSHPDR 2013*,[14] *WSHPDR 2016*,[29] Eurostat[30]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

In Slovenia, 540 water permits have been issued for SHP plants. From 2015 to 2017, 40 new water permits were issued in total: 16 in 2015, 10 in 2016 and 14 in 2017.[31] In 2016, there were 424 SHP plants operating and selling electricity to the grid with a total electricity production of 432 GWh. According to the size of the plants, the share of production from micro-hydropower plants (210 plants) was approximately 6 per cent, from small plants (194) it was approximately 50 per cent and from medium plants (20) it was approximately 44 per cent. Thus, SHP accounted for approximately 9 per cent of the electricity production from all hydropower.[3]

The last comprehensive analysis and planning of potential SHP projects on the national scale was carried out by the Energy Directorate of the Ministry of Economic Development and Technology in 2007. The study identified 33 SHP sites with capacities of 1-10 MW and 6 sites with smaller capacities.[10] Most of these sites, however, are not in line with the objectives of the Water Framework Directive (WFD) (e.g., achieving good ecological status) and are planned in protected areas of the Natura 2000 EU network. As of the writing of this report, of these plants, only five SHP projects were completed or were under construction. In 2017, no new SHP plants were commissioned in Slovenia.

The National Renewable Energy Action Plan 2010-2020 (NREAP 2010 - 2020) set the goal of increasing the installed capacity of SHP plants with a capacity of 1-10 MW by 16 MW.[6] The major challenge for SHP development is to harmonize RES and the ecological objectives, which is why activities to identify environmentally acceptable sites for SHP development have been started. The regulatory basis includes the guidance for the Alpine Space and Danube Basin with the consideration of Article 4.7 of the Water Framework Directive and Article 6.4 of the Habitats Directive. Both the Water Framework Directive (WFD) and the Habitats Directive state that public interest must be considered and the benefits of new electricity production must outweigh the environmental benefits.[24,26] The main principle to be followed is that the higher the ecological value of a water stretch (waterbody), the higher the energy output should be. Therefore, regulations favour the development of larger hydropower, while SHP plants are usually foreseen on already deteriorated stretches with the focus on optimizing the existing exploitation as well as on sites of potential multipurpose use (e.g., flood and erosion protection, irrigation, water supply, etc.).

An investment incentive with the total amount of EUR 26 million (US$ 30.6 million) from Cohesion Fund was launched for the period 2014-2020 to stimulate the production and distribution of energy from the renewable energy sources, specifically for the construction of new smaller facilities for the production of electricity from RES (wind, solar, biomass and small hydropower of up to 10 MW). The investment is expected to stimulate the construction of plants with a total additional capacity of 50 MW.[28]

In Slovenia, financial support is provided to SHP projects through two schemes – Operating support (OS) and Guaranteed purchase (GP). Both are provided for a period of 15 years for new projects. The level of support is defined each year and does not affect plants which are already included in the support scheme (Table 1).[2]

Table 1.
Financial support of small hydropower projects in 2016

Scale of the project	*Tariffs (EUR/MWh (US$/MWh))*	
	Operating support	*Guaranteed purchase*
Micro	71.37 (83.99)	105.47 (124.12)
Small	58.51 (68.86)	92.61 (108.99)
Medium	46.66 (54.91)	82.34 (96.90)**
Large	40.89 (48.12)*	–

Source: Borzen[2]

Note: * for plants with a capacity up to 125 MW; ** for plants with a capacity up to 5 MW.

Renewable energy policy

The main strategic action plan considering renewable energy in Slovenia is the National Renewable Energy Action Plan (NREAP), which defined the target of 25 per cent of RES in final energy consumption by 2020. It also covers such topics as the national policy on renewable sources of energy (last updates adopted in December 2017), the expected gross final energy consumption in the period between 2010 and 2020, targets and trajectories for the renewable energy sources, measures for achieving the binding target shares of renewable energy sources and the estimation of the contribution of individual technologies, and an estimation of the costs of carrying out measures as well as of the impacts on the environment and on the creation of jobs.[6] The Government of Slovenia has adopted two strategic documents that strive for a low-carbon society and economy – Agenda 2030 and Development Strategy 2030.[7,9] Both documents promote the development of renewable energy sources as the basis for a more sustainable society and economy.

In line with the requirements of the Water Framework Directive (WFD), the Republic of Slovenia faced the need for cross-sectoral coordination of the development goals and objectives of achieving or maintaining a good status of waters. A draft document for the establishment of exceptions under Article 4.7 of the WFD was drawn up. The purpose of the document was to specify the starting points for the implementation of the procedure for justifying an exemption under Article 4.7 of the WFD. A draft concept of procedure and starting points for the criteria of justifying an exception for new water uses was prepared. As of the moment of writing the present repot, the document was not approved.

The competent authority responsible for the energy sector is the Energy Directorate within the Ministry of Infrastructure (previously within the Ministry of the Economy). In the measure "Proactive role of the state in identifying environmentally acceptable locations for exploiting hydropower potential", it is stated that the Ministry of the Environment and Spatial Planning will ensure the processing of already received petitions to initiate the procedure for allocating water rights for the SHP projects and the Ministry of the Economy will undertake a study of the costs and benefits of existing SHP plants, as a basis for sustainable criteria, wherein it takes account of the environmental, social and economic impacts. [6]

In general, the support for hydropower development in Slovenia is mixed, and comprehensive studies are necessary to prepare a Master plan defining potential sites considering the environmental objectives. Such a plan would need to be prepared and adopted among sectors. This need has been widely recognized and already supported by numerous studies and documents.[1,11,13,15,23,24] It is important to raise public acceptance of SHP, in particular those projects that can produce not just renewable energy but also green energy. This requires a full mobilization of the mitigation measures to minimize negative effects on the aquatic ecosystems and water status and also ensure synergies with the other water management related objectives, such as flood risk mitigation and water supply.

Barriers to small hydropower development

The major barriers to small hydropower development in Slovenia include:

- A lack of the efficient collaboration between sectors, with each sector following its own objectives and not properly applying the principles of the sustainable development, which is an important framework for managing the resources in a holistic way, coordinating and integrating environmental, economic and social aspects in an equal manner.
- A lack of human and financial resources, with a significant reduction observed since 1990, especially compared to the growth of national GDP over this period. This translates into inadequate data management, lack of supervision and stronger position of water management objectives in spatial planning and land use, inadequate maintenance of the water infrastructure and watercourses and also in unclear and non-straightforward decision making.
- The administration of the water sector has been periodically reorganized, which leads to the lack of know-how among the officials.
- There is mistrust surrounding new SHP development, especially in the nature protection sector, since many of the existing SHP plants do not follow obligations of ensuring the environmental flow and meeting other requirements related to the aquatic ecosystem protection.
- There exists inadequate technical, economic, environmental and risk awareness on the investors' side, especially the smaller ones, who are not always aware of the fact that investment in SHP projects with full consideration of all technical, safety and environmental aspects can require considerable time and financial resources.

Thus, there is a need for better data generation and harmonization, improved stakeholder involvement and communication, integration of the multiple decision support tools for integrated water management and implementation of the strategic (spatial) planning approaches.

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4.1.11

Spain

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Key facts

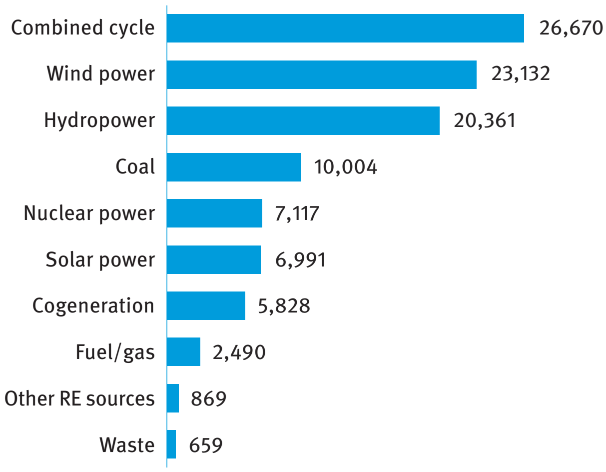
Population	46,572,028[1]
Area	505,000 km[2]
Climate	The climate is temperate with clear and hot summers in the interior of the country and more moderate and cloudy summers along the coast. Winters are cloudy and cold in the interior and partly cloudy and cool along the coast. Average temperatures range between 6.6 °C in January and 22 °C in July.[2]
Topography	The terrain comprises a large, flat to dissected plateau surrounded by rugged hills with an average height of 610 metres above sea level. In the north, the Pyrenees stretch approximately 400 km from the Atlantic coast, and the mountains of the Cordillera Betica and Sierra Nevada transverse the far south. The highest point of mainland Spain is Mulhacen at 3,481 metres above sea level.[3]
Rain pattern	Average annual precipitation is 650 mm. In northern Spain, rainfall reaches 1,000 mm, while in semiarid areas it is only 300 mm. The driest months are June to September, while the wettest is November, with an average of 73 mm.[2]
Hydrology	There are approximately 1,800 rivers in Spain, though many stay dry for much of the year. When filled with water, rivers quickly turn into raging and destructive torrents. Five major rivers follow the direction of the major mountain systems, with four of them flowing into the Atlantic Ocean (the Duero, Tagus, Guadalquivir and Guadiana) and one (the Ebro) into the Mediterranean Sea. All of these rivers are dammed, as well as many of their numerous tributaries, and the reservoirs provide much of the water and electrical power for the country.[3]

Electricity sector overview

As of the end of 2017, Spain (the Iberian Peninsula, the isolated island network also known as the Balearic and the Canary islands as well as Ceuta and Melilla) had a total installed capacity of 104,121 MW, comprised of 25 per cent from combined cycle gas turbine plants, 22 per cent from wind power, 19 per cent from hydropower, 10 per cent from coal-fired plants, almost 7 per cent from nuclear power, also almost 7 per cent from solar power each, 6 per cent from cogeneration, 2 per cent from fuel- and gas-fired plants and approximately 1.5 per cent from renewable and non-renewable waste and other renewable energy sources combined (see Figure 1). Thus, in 2017 the installed capacity of Spain decreased for the second consecutive year, which was mainly due to the definitive shutdown of the 455 MW Santa Maria de Garoña nuclear plant, which had been inactive since 2012. Of the total installed capacity, 46.3 per cent corresponded to renewable energy sources.[4]

The net demand in 2017 was 268,140 GWh, indicating a continuation of the growth trend that began in 2015, with a 0.4 per cent increase from 2016. In 2017, Spain generated 262,645 GWh of electricity, which was 0.1 per cent more than in 2016. Hydropower production, including pumped-storage hydropower plants, accounted for 20,613 GWh. This was the lowest value registered since 2005 and was caused by the abnormally low rainfall.[4]

Figure 1.
Installed electricity capacity by source in Spain (MW)



Source: Red Electrica de España[4]

The Ministry of Industry, Energy and Tourism (Minetur) is responsible for formulating and implementing energy policy. The regulator for the energy sector is the National Commission of Markets and Competition (CNMC). The CNMC also cooperates with other regulators through the Council of European Energy Regulators (CEER) and the Agency for the Cooperation of Energy Regulators (ACER) for interconnections between neighbouring countries. In terms of installed capacity, the largest companies are Iberdrola, Endesa and Gas Natural Fenosa, which together control approximately 75 per cent of the capacity.[5]

The Spanish wholesale market is part of the Iberian power market (Mercado Ibérico de Electricidad – MIBEL), which includes Spain and Portugal. OMIE in Spain manages the spot market, while OMIP in Portugal manages the futures market. Red Eléctrica de España (REE) and Red Eléctrica Nacional (REN) are the two system operators.[5]

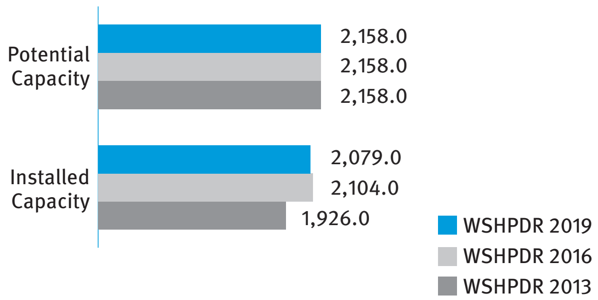
The Spanish transmission network is owned and operated by REE. In 2017, the transmission network had a total length of 43,930 km, of which 21,728 km was at 400 kV, and included 5,719 substations with a transformer capacity of 86,654 MVA.[4]

Endesa, Iberdrola, Gas Natural Fenosa, E.ON and HC Energia-EDP are the five major distributors. However, there are more than 300 smaller companies that also provide distribution services.[5] The electrification rate in Spain is 100 per cent.[6] The average electricity price for household consumers including taxes in the second half of 2017 was 0.22 EUR/kWh (0.26 US$/kWh).[7]

Small hydropower sector overview

The definition of small hydropower (SHP) in Spain is an installed capacity up to 10 MW. In 2017, the SHP installed capacity was 2,079 MW from 1,078 plants.[8] The SHP potential is estimated at 2,185 MW.[9] Between the *World Small Hydropower Development Report* (*WSHPDR*) *2016* and *WSHPDR 2019*, installed capacity has decreased by 25 MW (1 per cent) and the SHP potential remained the same (Figure 2). The decrease in installed capacity is due to the crisis the SHP sector is currently undergoing, with a number of plants having been closed. SHP generation is highly dependent on water availability. In 2017, as a result of low rainfall, electricity generation from SHP plants fell to 3,900 GWh, which was 33 per cent less than in 2016.[8]

Figure 2.
Small hydropower capacities 2013/2016/2019 in Spain (MW)



Source: CNMC,[8] Espejo Marín,[9] *WSHPDR 2016*,[10] *WSHPDR 2013*[11]

Note: The comparison is between data from *WSHPDR2013*, *WSHPDR2016* and *WSHPDR2019*.

Most of the installed SHP capacity (63 per cent) is concentrated in four autonomous communities of the country: Galicia, Catalonia, Aragon and Castile and León. The first three of these also account for the majority of electricity generated from SHP – 61.5 per cent (Table 1).[8]

From 1998 to 2017, the number of SHP plants has grown by 61 per cent and the SHP installed capacity has grown by 60 per cent. However, both values peaked in 2016, showing a small decrease in 2017.[8] The SHP plants have an important impact on the Spanish economy. In 2016, the SHP industry contributed EUR 323 million (US$ 375 million) to the national GDP, which represents a decrease of approximately 17 per cent compared to 2015. This reduction was caused by a fall in prices due to increased electricity production. As a result of the lack of new projects and automation of some of the already existing SHP plants, the number of people employed in the sector has been decreasing since 2009, with a 19 per cent decrease between 2009 and 2016.[12]

The total theoretical hydropower potential in Spain is estimated at 150,360 GWh/year, the technically feasible potential is 65,600 GWh/year and the economically feasible potential is 34,000 GWh/year. The SHP potential generation has been estimated at 6,700 GWh/year.[13]

Table 1.
Installed SHP capacity and generation by region (MW)

Region	*Capacity (MW)*	*% of Spain*	*Generation (GWh)*	*% of Spain*
Andalusia	141	6.8	147	3.8
Aragon	258	12.4	627	16.1
Asturias	76	3.7	157	4.0
Canary Islands	1	0.0	3	0.1
Cantabria	72	3.5	131	3.4
Castilla- La Mancha	123	5.9	159	4.1
Castile and León	254	12.2	343	8.8
Catalonia	285	13.7	894	22.9
Valencian Community	31	1.5	13	0.3
Extremadura	23	1.1	16	0.4
Galicia	513	24.7	879	22.5
La Rioja	27	1.3	42	1.1
Madrid	44	2.1	56	1.4
Murcia	14	0.7	41	1.1
Navarre	167	8.0	288	7.4
Basque Country	50	2.4	104	2.7
Total	**2,079**	**100.0**	**3,900**	**100.0**

Source: CNMC[8]

Renewable energy policy

The resurgence of the SHP sector in Spain was due to the Government's support of the producers of renewable energy. The Electricity Sector Law (54/1997) set a special regulation for sources of renewable energy with an installed capacity below 50 MW. Furthermore, the Law recognizes the environmental benefits of these sources by granting financial benefits. Therefore, renewable energy sources can compete with traditional sources of energy.[10]

The Royal Decree 436/2004 of 12 March 2004, as developed upon the Electricity Sector Law, set the legal and economic framework for the Special Regime, in order to consolidate the rules and to give more stability to the system. The Royal Decree 661/2007, published on 25 May 2007, superseded the previous decree and added another regulation to the production system. This decree set a new system aimed at renewable energy plants in order to achieve the targets of the Renewable Energy Plan 2005-2010.[10]

The Spanish economic crisis, alongside the increase of tariffs, has led to the adoption of a series of contentious measures against renewable energy sources, as they were seen as the cause of this increase. The Royal Decree 6/2009 of 30 April 2009 set the quota for the maximum capacity that can be installed annually for all the renewable energy sources within the special regime. A register was created in order to allow plants falling under the special regime to get access to the financial benefits of the Royal Decree 661/2007. In the aforementioned register, renewable energy plants could only be registered if the limit of renewable energy plants has not been exceeded.[10]

At the beginning of 2013, the new Electricity Sector Law (24/2013) was issued. The law foresees the possibility in certain exceptional cases to establish retributive regimes in order to promote the production of renewable energy. The Royal Decree 413/2014 of 6 June 2014 regulates the generation of energy coming from renewable energy sources, cogeneration and waste.[10]

The 2020 targets for the renewable energy sector are defined in the National Renewable Energy Action Plan (NREAP), which follows the European Directive 2009/28/EC: 20.8 per cent share in gross final energy consumption, 17.3 per cent of heat consumption, 39 per cent of electricity demand, and 11.3 per cent of energy demand. The first NREAP of 30 June 2010 was replaced by a new NREAP of 20 December 2011.[14]

Legislation on small hydropower

There is currently no regulation published concerning the residual flow. A recommendation could be made in the sense that this flow should be variable during the year, to enable a better adjustment to the differences of the natural hydrological regime and to the spawning seasons.

Until 2012, there were two different support options (under the previous promotion scheme as established by the Royal Decree 661/2007), a feed-in tariff (FIT) and a market premium with a cap and a floor, on the sum of market price and premium. Plants with a rated power less than 10 MW as well as those with a rated power greater than 10 MW (but less than 50 MW) were considered small-scale hydropower plants. However, on 27 January 2012 the Spanish Council of Ministers approved a Royal Decree-Law 'temporarily' suspending the FIT pre-allocation procedures and removing economic incentives for new power generation capacity involving cogeneration and renewable energy sources (RES-E).[10] The move was a result of a tariff deficit of roughly EUR 26 billion (US$ 30.2 billion) in 2012, which was largely driven by the incentives for renewable energy sources.[5]

The 2014 Royal Decree 413/2014 (RD 413/2014) replaced renewable energy feed-in tariffs with a "reasonable return" of 7.4 per cent over the lifetime of a plant. It was introduced alongside the Order IET/1045/2014, which specifies various parameters for calculating the return for different types of renewable energy plants.[5,10]

Barriers to small hydropower development

Although SHP has played an important role in electricity generation in the country, SHP development currently faces several barriers:

- Hydropower projects have to compete with other water uses over the limited resources.
- The new economic regime of electricity generation makes SHP generation uneconomic.
- Some potential hydropower sites have not been studied in detail, thus there is a lack of knowledge regarding their actual potential.
- In order to use water for hydropower purposes, licences need to be issued, which requires an environmental authorization approval. The excessive waiting time to get approvals slows the development of potential projects.
- Difficulties in renewing the water concession periods of the current hydropower plants mean that there is the risk of some existing hydropower projects being abandoned.
- The administrative process to get a licence is complex, even for small projects.
- There are obstacles in the procedure of obtaining authorization from regional and local organs.[15]

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4.4 Western Europe

Miroslav Marence, IHE-Delft; and International Center on Small Hydro Power (ICSHP)

Introduction to the region

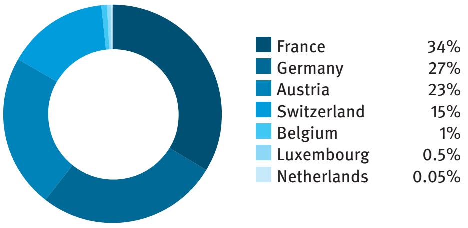
The region of Western Europe includes nine countries. Seven of these use small hydropower (SHP): Austria, Belgium, France, Germany, Luxembourg, Netherlands and Switzerland. The two countries of the region not covered in the present report are Liechtenstein and Monaco. The geography of the region is characterized by mountains in the south and south-east (Alpine region), hilly uplands and broad low plants in the north and north-west, with a small part of Mediterranean in the south-west. The dominant climate is continental and temperate, with a maritime climate along the coast.

An overview of the countries of Western Europe is given in Table 1. All countries of the region have 100 per cent access to electricity. As a part of the European market of the electrical transmission grids, all of these countries are strongly connected and work together under the coordination of the European Network of Transmission Systems (ENTSO-E). The national electrical grids, integrated in a cross-border electricity market, are challenged not to produce enough electricity, but to secure and stabilize the whole European grid under very rigorous criteria for grid variation in frequency and voltage.

The electrical energy portfolio is different from country to country depending on their strategy, as well as geographic and climate characteristics. Renewable energy sources in the north are ruled by onshore and offshore winds. Geothermal, biomass and solar power are being developed in all regions, especially in Germany with its strong renewable energy policies. In the Alpine region, large and small hydropower have a dominant role in electrical energy production. Thus, in Austria, hydropower contributes over 60 per cent of the country's annual electricity generation. The hydropower potential, especially of large hydropower, is nearly fully developed in the region, while some development is still possible in the SHP sector.

SHP accounts for approximately 1.5 per cent of the region's total installed electricity capacity and 9.7 per cent of the total hydropower installed capacity. The regional leaders in terms of SHP installed capacity are France, Germany and Austria, which together account for 84 per cent of the region's total (Figure 1).

Figure 1.
Share of regional installed capacity of small hydropower up to 10 MW by country in Western Europe (%)



Source: *WSHPDR 2019*[3]

In order for the European countries to achieve their renewable energy targets by 2020, including the integration of a large amount of wind and solar power into the European electricity transmission system, new infrastructure is crucial. New high voltage trans-boundary lines and sufficient electrical energy storage capacity are critical for network security and stability.

Table 1.
Overview of countries in Western Europe

Country	*Total population (million)*	*Rural population (%)*	*Electricity access (%)*	*Electrical capacity (MW)*	*Electricity generation (GWh/year)*	*Hydropower capacity (MW)*	*Hydropower generation (GWh/year)*
Austria	8.7	42	100	21,813	67,882	11,990*	42,906*
Belgium	11.3	2	100	21,066	80,290	142	2,409
France	67.1	20	100	130,761	529,400	25,517	53,600
Germany	82.7	23	100	207,932	654,000	13,399	28,000
Luxembourg	0.6	9	100	2,023	2,762	1,330*	1,530*
Netherlands	17.2	9	100	31,976	110,100	38	94
Switzerland	8.4	26	100	20,842	61,600	14,809*	36,300*
Total	**196.0**	-	-	**436,413**	**1,506,034**	**67,225**	**164,839**

Source: *WSHPDR 2019,*[3] WB,[4] WB,[5] FEBERG,[6] Swiss Federal Office of Energy[7]

Note: *Including pumped storage hydropower.

Small hydropower definition

All the countries of the region, except Germany, use the upper limit for SHP of 10 MW (Table 2). Germany, while accepting the 10 MW limit, uses the definition of SHP as projects up to and including 1 MW of installed capacity.

Regional small hydropower overview and renewable energy policy

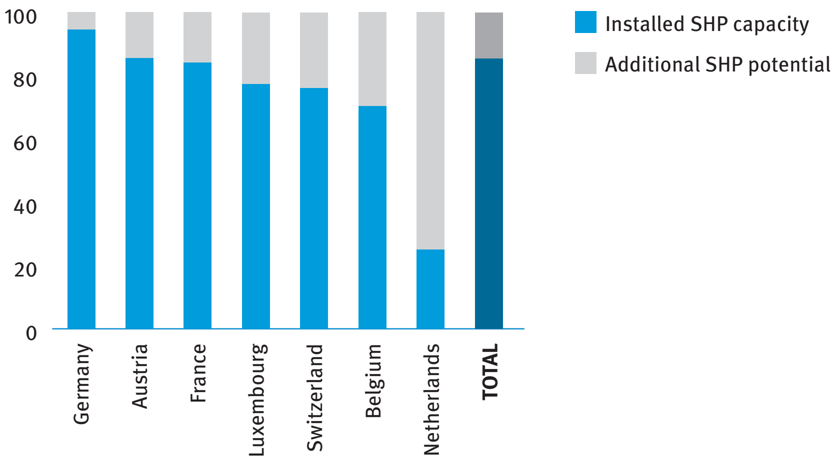
The region's total installed SHP capacity stands at 6,514 MW, with the individual countries' installed SHP capacities ranging from 3 MW in the Netherlands to 2,200 MW in France (Table 2). France is also the regional leader in terms of SHP potential, estimated at roughly 2,600 MW. The total potential of SHP up to 10 MW in Western Europe is estimated to be 7,634 MW, of which 85 per cent has been developed (Figure 2). However, a number of countries still lack a comprehensive estimate of their SHP potential, hence the actual potential in the region might be higher. Compared to the *World Small Hydropower Development Report (WSHPDR) 2016*, the region's installed capacity increased by approximately 5 per cent, with the most significant changes in absolute terms reported for Austria, France and Switzerland, while the capacity in Germany decreased (Figure 3).

Table 2.
Small hydropower capacities in Western Europe (local and ICSHP definition) (MW)

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed capacity (local def.)*	*Potential capacity (local def.)*
Austria	up to 10	1,523.0	1,780.0	1,523.0	1,780.0
Belgium	up to 10	72.8	103.4	72.8	103.4
France	up to 10	2,200.0	2,615.0	2,200.0	2,615.0
Germany	up to 1	N/A	N/A	1,731.0	1,830.0
Luxembourg	up to 10	34.0	44.0	34.0	44.0
Netherlands	up to 10	3.0	12.0	3.0	12.0
Switzerland	up to 10	950.0	1,250.0	950.0	1,250.0
Total		-	-	**6,514**	**7,634**

Source: *WSHPDR 2019*[3]

Figure 2.
Utilized small hydropower potential by country in Western Europe (local SHP definition) (%)



Source: *WSHPDR 2019*[3]

Note: This Figure illustrates data for local SHP definitions, except for Germany, for which data for SHP up to 10 MW is used.

An overview of SHP in the countries of Western Europe is outlined below. The information used in this section is extracted from the country profiles, which provide detailed information on SHP capacity and potential, among other energy-related information.

Austria has 3,262 SHP plants with a total installed capacity of 1,523 MW and a production of 6,853.8 GWh per year. While there is no reliable data on the SHP potential, the Austrian Government set the target of achieving 1,780 MW of SHP capacity, implying that at least this potential is available, 86 per cent of which has already been developed. Compared to the results of the *WSHPDR 2016*, the installed capacity increased by 11 per cent.

The installed capacity of SHP in **Belgium** is 72.8 MW from 154 sites, while the economic potential is estimated to be 103.4 MW, indicating that more than 70 per cent has been developed. The change in installed capacity compared to the *WSHPDR 2016* is due to refurbishments and new installations. In particular, as a result of refurbishment works the capacity of the 10 MW Lixhe plant reduced by 7 MW and the capacity of the Andenne plant reduced by 1.9 MW. Another 7 MW from six plants was installed on navigable waterways, with the remainder coming from very small installations or refurbishments below 100 kW.

France is the regional leader in terms of SHP with an installed capacity of 2,200 MW. The potential is estimated at 2,615 MW, indicating that 84 per cent has been developed. Since the *WSHPDR 2016*, the installed capacity increased by 8.9 per cent. In April 2016, the Government launched the first call for SHP projects to promote the construction of new green fields and upgrade the equipment of existing dams, with 19 projects with a combined capacity of 27 MW selected. A new call for tenders for 105 MW of SHP was announced in April 2017.

The installed capacity of SHP up to 10 MW in **Germany** amounts to 1,730.8 MW. It is estimated that there are 7,110 operational hydropower plants with capacity less than 10 MW. However, since many micro- and pico-hydropower plants are used for self-consumption and are difficult to identify, it is likely that there could be a further 300-400 very small-scale plants in operation.

Compared to the *WSHPDR 2016*, the installed capacity decreased by 5.2 per cent, while potential capacity remained unchanged at 1,830 MW.

Both installed and potential capacities of SHP in **Luxembourg** have remained unchanged, standing at 34 MW and 44 MW, respectively. Thus, 77.3 per cent of the currently known potential has been developed. However, this estimate of the potential is based on the 2020 target, according to which at least a further 10 MW should be developed, while the total available potential remains unknown. Both the public and the private sector are planning to conduct further feasibility studies and disseminate SHP.

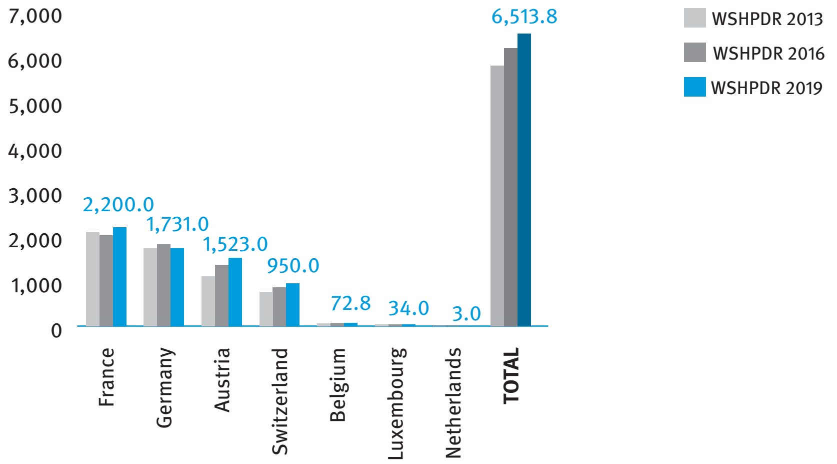
The topography of the **Netherlands** is dominated by lowlands and reclaimed land (polders). As a result, hydropower potential is low and mostly derives from the existing water management works needed for flood control and navigation measures. Total installed hydropower capacity in the Netherlands is 38 MW, of which SHP accounts for 3 MW. SHP potential in the country is estimated at 12 MW. Since the *WSHPDR 2016*, both installed and potential capacities remained unchanged.

There are approximately 1,690 SHP plants in operation in **Switzerland**. Their combined installed capacity is approximately 950 MW and annual production is approximately 4,006 GWh. This represents roughly 12 per cent of the total hydropower capacity. The SHP potential is estimated at 1,250 MW, indicating that 76 per cent has been developed to date. The best sites have already been developed, while the exploitation of the remaining potential is under debate due to economic and ecological constraints.

SHP support mechanisms exist in all countries through tradable green certificates, investment support or subsidies, feed-in tariffs, market premium and premium tariffs. **Feed-in tariffs (FITs)** are in place in Austria, France, Germany, Luxembourg and Switzerland.

In the recent years, new SHP development in Western Europe has been greatly affected by environmental legislation, especially for sites in designated areas, such as Natura 2000, and sites affected by the Water Framework Directive, among others. The Water Framework Directive is being implemented in all European Union member states (only Switzerland is not part of the European Union).

Figure 3.
Change in installed capacity of small hydropower from *WSHPDR 2013* to *2019* by country in Western Europe (MW)



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

Note: *WSHPDR* stands for *World Small Hydropower Development Report.*

Barriers to small hydropower development

All countries have to increase their renewable energy share by 2020. The endeavoured share of the renewable sources in the energy mix is different for each of the countries, ranging from 34 per cent in Austria to just 14 per cent in the Netherlands. The difference is due to the regional availability of renewable energy resources. The main natural limitation for hydropower development is the availability of local hydrological potential, especially hydraulic head. In the countries with a low head potential such as the Benelux countries or northern Germany, additional promising hydropower potential exists in the installation of the plants on existing navigation and flood control weirs.

With higher environmental expectations regarding hydromorphology due to the implementation of the European Water Framework Directives, strict environmental conditions (ecological minimum flow, fish up- and downstream migration possibility, fish friendly turbines, free sediment transport along rivers and influence of flow variation by hydropeaking) restrict energy production and jeopardize technical and economic viability of new and also existing projects. Licensing procedures of completely new hydropower sites must include comprehensive assessments of environmental (including limnological) concerns with respect to the European, national and federal regulations but also the welfare of stakeholders such as fisheries, tourist or recreation groups.

In addition to the environmental constraints, the major barriers to SHP development in **Austria** are a very low market price for electricity, which is in particular creating pressure on plants with capacity higher than 2 MW and for operators who are obliged to invest in fish bypass systems or build/refurbish a plant with investment support. Although in general public opinion on SHP is positive, some opposition to local development from local communities may cause delays in the realization of projects.

Hydropower has historically been extensively exploited in **Belgium**. However, further SHP development is challenged by higher environmental requirements that investors have to comply with. A change in regulations to help clarify the environmental rules was expected in 2017 but has still not materialized.

There are multiple barriers to SHP development in **France**, including the prohibition of new works on the rivers ranked in List 1, while the owners of hydropower plants located on rivers ranked in List 2 are supposed to carry out heavy and expensive installations to ensure the transport of the sediments and the circulation of migratory fishes. Producers face financial obstacles associated with the environmental requirements as well as the low market price of electricity from SHP for projects that cannot benefit from FITs based on their installed capacity or due to the lack of installations to ensure the transport of the sediments and the circulation of migratory fish.

The development of SHP in **Germany** faces barriers of different types related to complex licensing procedures for both existing and new plants. Another barrier is the high cost of the required hydraulic structures and operation modes.

Some of the most relevant barriers to SHP development in **Luxembourg** are the lack of well-defined energy strategy after 2020, a low SHP potential, the greater focus of research and development policies on solar and wind power technology, and the lack of feasibility studies. Also, the country strongly relies on its neighbours with regards to electricity produced through small hydropower and other renewables, therefore, there is no motivation to implement or approve construction of future projects

The main limitations for SHP development in the **Netherlands** include the low hydrological potential due to the flat relief, the reluctance of local water communities to issue permits and the opposition of fishermen to hydropower development.

The development of new SHP projects in **Switzerland** is hampered mainly by conflicts with other water uses/rights in densely populated (lowland) areas, difficulties to find appropriate and cost-effective solutions for accessing electricity transmission lines for greenfield projects in natural creeks, the poorly engineered projects leading to the overestimation of the production and underestimation of costs and the excessive production of legal and regulatory documents.

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Austria

4.4.1

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Key facts

Population	8,739,806 [1]
Area	83,878.99 km²
Climate	Austria has a temperate continental climate. Winters, between December and January, are cloudy and cold with frequent rain and some snow in the lowlands and snow in the mountains. Winter temperatures average between –7 °C and –1 °C. Summers, between June and August, are moderate with occasional showers. Temperatures in July average between 18 °C and 24 °C. There are three climatic regions in the country. The eastern region is characterized by Pannonian climate with continental influence, low precipitation, hot summers, and moderately cold winters. The Alpine region has Alpine climate with high precipitation (except the inner Alpine valley regions such as the upper Inntal), short summers, and long winters. The remainder of the country has a transient climate influenced by the Atlantic in the west and a continental influence in the south-east.[2]
Topography	Austria is mountainous in the south and west (the Alps), although along the eastern and northern borders the country is mostly flat or gently sloping. Alpine regions cover 67 per cent (56,244 km²) of the total land area. The highest point is Grossglockner at 3,798 metres.[2]
Rain pattern	Rainfall ranges from more than 1,020 mm annually in the western mountains to less than 660 mm in the driest region, near Vienna.[2]
Hydrology	Austria is situated in three transboundary river basins: Danube, Rhine, and Elbe. Overall, there are 7,339 rivers and 62 lakes. Approximately 96 per cent of the territory belongs to the Danube River basin, which has an average flow of 1,955 m³/sec at the border with Slovakia. Approximately 3 per cent of the territory is part of the Rhine basin and 1.1 per cent of the Elbe River basin.[2]

Electricity sector overview

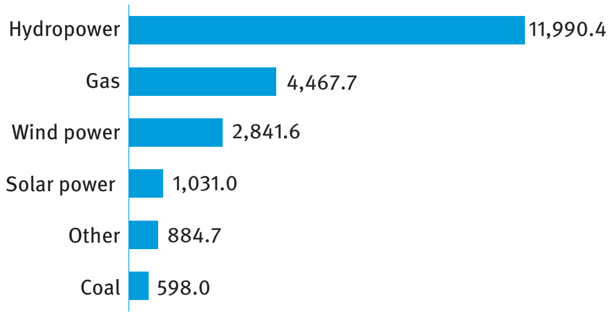
As of November 2017, total installed electrical capacity in Austria was 21,813.4 MW. More than half, 55 per cent, was from hydropower plants, including pumped storage facilities. Approximately 20 per cent came from gas-powered plants, 13 per cent from wind power, 5 per cent from solar power, 3 per cent from coal, and the remainder from other sources including oil, biomass, and geothermal resources (Figure 1).[3] Compared to the *World Small Hydropower Development Report (WSHPDR) 2016*, the country's total installed capacity decreased due to the phase-out of coal power. At the same time, the installed capacity of renewable energy sources as well as gas power increased.[4]

In 2016, the total electricity generation in Austria was 67,882 GWh, with hydropower (including small hydropower) having contributed 42,906 GWh, or approximately 63 per cent (Figure 2). The total share of renewable energy in electricity generation was approximately 72 per cent. A further 26,366 GWh was imported, with the majority of imported electricity coming from Germany (59 per cent) and the Czech Republic (36 per cent). Electricity exports in 2016 amounted to 19,207 GWh. [5]

The electrification rate in Austria is 100 per cent and there is 100 per cent connection to the national grid with the exception of some remote mountain lodges.[4] Following the Austrian Electricity Industry Organisation Act (EIWOG) adopted in 2000, the Austrian electricity market became fully liberalized by adopting an unbundled market structure with E-Control operating as the state-owned independent regulatory authority. Verbund is the largest electricity provider, covering approximately 40 per cent of the country's electricity demand, with almost 90 per cent of its generation coming from hydropower plants. The company also has purchase rights for electricity generated from 20 hydropower plants owned by several other companies. Verbund is listed on the Vienna Stock Exchange as well as the Austrian Traded Index (ATX) with the Government of Austria as the majority shareholder with 51 per cent of the shares.[6] Other significant hydropower producers include Energie AG Oberösterreich, Energie Steiermark, EVN Group, KELAG, Salzburg AG, TIWAG-Tiroler Wasserkraft AG, Vorarlberger Kraftwerke AG and others. Electricity is traded over-the-counter or on an energy exchange such as the European Energy Exchange (EEX) or the Energy Exchange Austria (EXAA). The EXAA is a public limited company owned by the Vienna Stock Exchange as well as a number of different companies from the Austrian energy sector, which operates a day-ahead electricity spot market. The Austrian Power Grid (APG), a 100 per cent subsidiary of Verbund AG, operates the transmission grid, which is part of the trans-European transmission grid.[4]

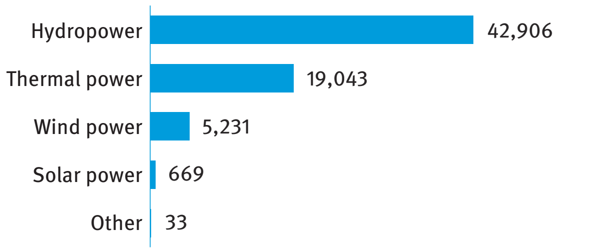
The price for Austrian electricity consumers is based on three components: the amount charged by the supplier, which is set by individual suppliers; a network charge to the system operator, which is set by E-Control and based on the grid connection of individual consumers; and taxes and surcharges levied by the Government, including value-added tax (VAT). In 2016, the average gross cost, including energy taxes and VAT, was EUR 0.202 (US$ 0.213) per kWh for households and EUR 0.096 (US$ 0.101) per kWh for industrial users.[7]

Figure 1.
Installed electricity capacity by source in Austria (MW)



Source: Austrian Power Grid[3]

Figure 2.
Annual electricity generation by source in Austria (GWh)

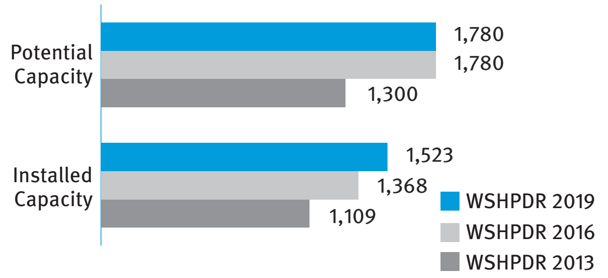


Source: Federal Ministry of Sustainability and Tourism[5]

Small hydropower sector overview

Regulated by ÖNORM (Austrian Standards), small hydropower (SHP) is defined as plants with a maximum capacity of 10 MW.[8] As of December 2016, Austria had an estimated total installed SHP capacity of 1,523 MW with a valued production (based on average 4,500 full load hours) of 6,853.8 GWh from 3,262 plants.[9] There is no reliable data on the potential capacity of SHP in the country. However, the Government set the target of achieving 1,780 MW of SHP capacity, implying that at least this potential is available, 86 per cent of which has already been developed. The Stream Map project coordinated by the European Small Hydropower Association also detailed the SHP potential within the country as 3,350 MW of theoretical potential, 2,450 MW of technically feasible potential and 2,100 MW of economically feasible potential. However, economic potential, taking environmental constraints into account, was estimated at 1,650 MW as of 2009.[16] Compared to the results of the *World Small Hydropower Development Report (WSHPDR)* 2016, the installed capacity of SHP in Austria increased by 11 per cent, while potential has not changed (Figure 3). The evolution of SHP installed capacity and electricity generation in Austria is shown in Figure 4.

Figure 3.
Small hydropower capacities 2013/2016/2019 in Austria (MW)

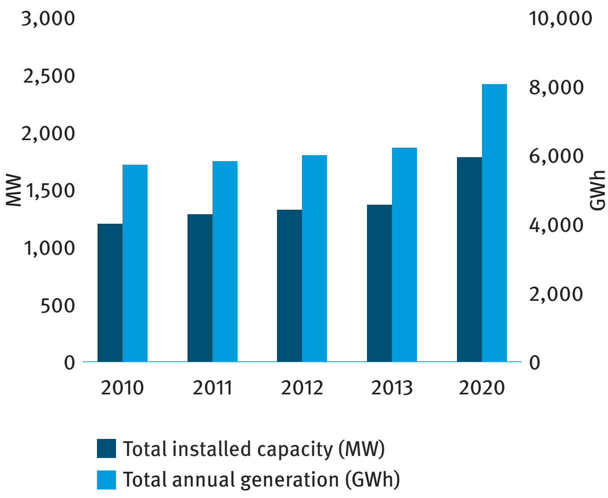


Source: *WSHPDR 2016*,[4] Energie-Control Austria,[9,17] *WSHPDR 2013*[18]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

The 3,262 SHP plants identified above are certified as Green Power Plants by the Austrian authorities.[9] However, not all SHP plants are identified as such. Thus, the actual number of SHP plants, and therefore the total installed and generating capacity, might be significantly higher. Currently, SHP accounts for approximately 15 per cent of the total installed hydropower capacity and approximately 10 per cent of total annual generation. According to the Austrian Energy Strategy 2020, the target for SHP is to achieve a generation of 8,000 GWh, from an installed capacity of approximately 1,780 MW by 2020 (Figure 4).[19] Studies in three out of the nine federal states in Austria showed that there is still potential for SHP development.[20,21,22]

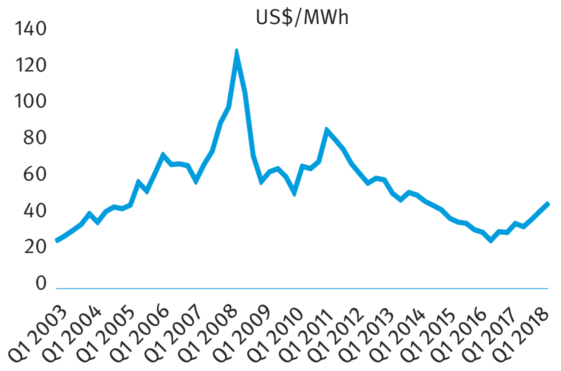
Figure 4.
Small hydropower capacity and annual electricity generation in Austria, 2010 - 2020



Source: ESHA,[16] Erneuerbare Energie Österreich[19]

Approximately 85 per cent of the total electricity produced by SHP plants in Austria receives a market price. In most cases, the plant operator sells directly to a trader in the private sector. In very few cases, the electricity is traded at the European Energy Exchange (EEX) platform in Leipzig, Germany. In both instances, the obtained price is strongly linked to the Phelix Base Quarter Future derivatives, which is traded at EEX. A market-based purchase price determined on the Phelix Base Quarter Future is also settled in the Austrian Green Electricity Act (ÖSG), which was last amended in 2012. This price is determined quarterly by Energie-Control Austria (Figure 5).[15,4]

Figure 5.
Market price for small hydropower in Austria, 2003 - 2018 (US$/MWh)



Source: Energie-Control Austria[10]

The federal states of Austria had individual tariff regulations before 2003. In 2003, a new tariff system was introduced country-wide. The tariff was dependent on the amount of electricity fed into the public grid. The tariffs varied between new SHP plants or plants undergoing refurbishment to increase the mean annual production or capacity by more than 50 per cent and plants undergoing refurbishment to increase the mean annual production or capacity by more than 15 per cent (Table 1).[11,4]

Table 1.
Small hydropower feed-in tariffs in Austria, 2003

	Tariff (EUR (US$) per MWh)	
Electricity delivered to the grid	*New SHP or refurbishment >50%*	*Refurbishment >15%*
≤ 1 GWh	62.5 (72.95)	59.6 (69.57)
Next 4 GWh	50.1 (58.48)	45.8 (53.46)
Next 10 GWh	41.7 (48.68)	38.1 (44.47)
Next 10 GWh	39.4 (45.99)	34.4 (40.15)
> 25 GWh	37.8 (44.12)	33.1 (38.64)

Source: Energie-Control Austria[11]

New plants and those which were refurbished with a more than 50 per cent increase of annual production or installed capacity between 2003 and 2005 receive feed-in tariffs for 15 years, whereas plants that were refurbished with a more than 15 per cent increase of annual production or installed capacity between 2003 and 2005 receive feed-in tariffs for 13 years.[23] Since the Green Electricity Act was amended in 2012, new SHP plants (or those undergoing refurbishment that increases the mean annual production or capacity by more than 15 per cent) with a capacity below 2 MW can choose between investment support or the feed-in tariffs as shown in Table 2 and Table 3. SHP plants above 2 MW have to take an investment support as shown in Table 2. The feed-in tariffs for 2018 are shown in Table 3 and the feed-in tariffs for 2019 are shown in Table 4.

Table 2.
Small hydropower investment support system in Austria, 2018

Installed capacity	*Support description*
< 50 kW	1,750 EUR/kW (2,165 US$/kW)
50 – 100 kW	1,750 EUR/kW (2,165 US$/kW) up to max. 35 per cent of the eligible investment costs
100 – 500 kW	1,750 EUR/kW (2,165 US$/kW) up to max. 35 per cent of the eligible investment costs
500 – 2,000 kW	1,750 – 1,250 EUR/kW (2,165 – 1,545 US$/kW) up to max. 35 – 25 per cent of the eligible investment costs, need of investment support must be proved with dynamic investment appraisal
2,000 – 10,000 kW	1,250 – 650 EUR/kW (1,545 – 805 US$/kW) up to max. 25 – 15 per cent of the eligible investment costs, need of investment support must be proved with dynamic investment appraisal

Source: Energie-Control Austria[12]

Table 3.
Small hydropower feed-in tariffs for new and refurbished plants in Austria, 2018

Delivered electricity	*Feed-in tariffs (EUR (US$) per kWh)*	
	Refurbishment > 15%	*New SHP or refurbishment > 50%*
< 500 MWh	0.0860 (0.1064)	0.1030 (0.1275)
Next 500 MWh	0.0683 (0.0845)	0.0844 (0.1045)
Next 1,500 MWh	0.0583 (0.0722)	0.0732 (0.0906)
Next 2,500 MWh	0.0359 (0.0444)	0.0446 (0.0552)
Next 2,500 MWh	0.0331 (0.0410)	0.0409 (0.0506)
> 7,500 MWh	0.0254 (0.0314)	0.0323 (0.0400)
For power buoys < 500 MWh		0.1300 (0.1609)
For power buoys > 500 MWh		0.1202 (0.1488)

Source: Energie-Control Austria[13]

Table 4.
Small hydropower feed-in tariffs for new and refurbished plants in Austria, 2019

Delivered electricity	*Feed-in tariffs (EUR (US$) per kWh)*	
	Refurbishment > 15%	*New SHP or refurbishment > 50%*
< 500 MWh	0.0851 (0.1053)	0.1020 (0.1262)
Next 500 MWh	0.0676 (0.0837)	0.0836 (0.1035)
Next 1,500 MWh	0.0577 (0.0714)	0.0725 (0.0897)
Next 2,500 MWh	0.0355 (0.0439)	0.0442 (0.0547)
Next 2,500 MWh	0.0328 (0.0406)	0.0405 (0.0501)
> 7,500 MWh	0.0251 (0.0311)	0.0320 (0.0396)
For power buoys < 500 MWh		0.1287 (0.1593)
For power buoys > 500 MWh		0.1190 (0.1473)

Source: Energie-Control Austria[13]

Renewable energy policy

The Austrian Climate and Energy Strategy "#mission2030" aims to reduce the country's greenhouse gas emissions by 36 per cent by 2030, as compared to the year 2005. This goal should be achieved by increasing the share of renewable energy sources to 45-50 per cent of the total energy demand. By 2030, 100 per cent of electricity produced in Austria should come from renewable sources. The transport sector, as well as the energy used for heating, should entirely come from renewable sources by 2050. Small hydropower plants play an important role in the #mission2030 strategy. In order to ease the strain on the electric grid and to gain more grid stability, energy production should become more decentralized.[14]

The Austrian Eco-Electricity Act 2012 entered into force on 1 July 2012 and includes the following innovations:

- A one-off payment of approximately EUR 110 million (US$ 119.5 million) to reduce the waiting list for wind, photovoltaics and small-scale hydropower projects;
- Raising of the former annual subsidization budget of EUR 21 million (US$ 22.8 million) to EUR 50 million (US$ 54.3 million). Within 10 years this budget will be reduced annually by EUR 1 million (US$ 1.1 million), to an amount of EUR 40 million (US$ 43.5 million);[12]
- New binding eco-electricity targets for the year 2020 based on gains in capacity and generation for eco-electricity generated from hydropower, wind energy, biomass, biogas, and photovoltaics;
- There will again be separate subsidization budgets for the individual technologies;
- The raw material surcharge for biogas plants was further developed and became a surcharge on operating costs;
- Useful incentives and measures to further enhance the efficiency of the subsidization scheme and the eco-electricity projects submitted;
- Restructuring of the funding tools, including greater transparency in connection with considerable concessions for low-income households and energy-intensive enterprises.[15,4]

In June 2017, the Austrian Federal Government passed an update of the Eco-Electricity Act (2012) as well as of the Electricity Management and Organization Act. One of the most significant changes for the Austrian small hydropower industry is the increase of the yearly available amount of money for supported feed-in tariffs from EUR 1.5 million (US$ 1.8 million) to EUR 2.5 million (US$ 2.9 million). In order to reduce the waiting list for promotions, there was an additional and non-recurring contingent of EUR 2.0 million (US$ 2.3 million) in 2017 and EUR 1.5 million (US$ 1.8 million) in 2018. The yearly contingent for investment supports was also increased by EUR 4 million (US$ 4.7 million) to EUR 20 million (US$ 23.3 million). All subsidy rates were raised by 5 percentage points. This leads to a subsidy rate of maximum 35 per cent for plants with a capacity of up to 500 kW, maximum 25 per cent for plants with a capacity of up to 2 MW and maximum 15 per cent for plants with a capacity of up to 10 MW. Simultaneously the maximum absolute amount of supports per kW of installed capacity was raised by EUR 250 (US$ 291) each.[12]

Barriers to small hydropower development

The major barriers to SHP development in Austria are as follows:

- A very low market price for electricity, which has been below 40 EUR/MWh (53 US$/MWh) since the beginning of 2013, is creating pressure on the whole SHP sector, in particular for the plants with capacity higher than 2 MW and for the operators who are obliged to invest in fish bypass systems or build/refurbish an SHP plant with investment support;
- Requests from the Government regarding environmental concerns, such as fish bypassing and reserved flow, are increasing continuously, and sometimes the consensus reached is not stable and reliable;
- Although in general public opinion in relation to SHP is positive, some opposition to local development from local populations may cause delays in realization of the project.[4]

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4.4.2 Belgium

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Key facts

Population	11,322,088[1]
Area	30,527.92 km^2 [2]
Climate	Belgium has a maritime climate, with mild summers and winters, and differences between the coastal zone and the mainland. The average temperatures in January range between 0.7 °C and 5.7 °C, and in July between 14 °C and 23 °C.[3]
Topography	Belgium is made up of a coastal plain in the north-west, central plateau (about 100 metres above the sea level) and Ardennes uplands in the south-east (south of the rivers Sambre and Meuse furrow) with the highest peak Signal de Botrange, 694 metres.
Rain pattern	Precipitation in the form of rain is significant: between 700 mm and 850 mm annually, on 200 days on average, with variability of about 25 days (230 days in the High Fens and 182 at the coast).[3]
Hydrology	Hydrology is projected to increase in the upcoming years due to climate change.[4]

Electricity sector overview

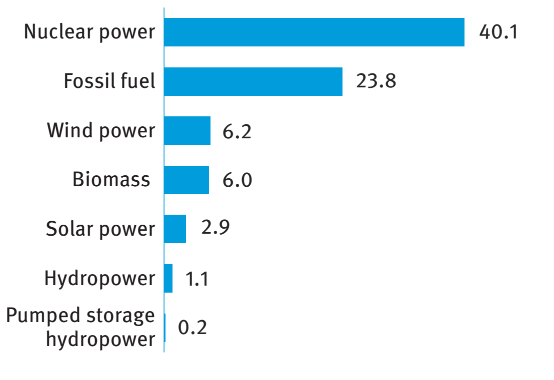
Belgium is a federal state of three regions: the Flemish region, the Walloon region, and Brussels – the Capital region. The evolution of the Belgian energy policy has been shaped by this system and has led to the transfer of wide competences from the federal state to the Regions.

The final gross energy consumption in 2015 was 416 TWh, with 86 per cent coming from fossil fuels and 6 per cent from nuclear energy. From 2005 to 2016, the renewable origin part in the final gross energy consumption increased from 2.3 per cent to 8.7 per cent (37 TWh).[5] The objective is to reach 13 per cent according to the European Directive on the promotion of the use of energy from renewable sources.[6] In 2016, total installed capacity was 21,066 MW, while the installed capacity for electricity production from renewable sources was 7,078 MW, from which 49 per cent was photovoltaics, 33 per cent was wind energy, 16 per cent was biomass and 2 per cent was hydropower.[7] The production of electricity from renewable sources in 2017 reached 3.8 TWh in Wallonia, 8.1 TWh in Flanders, 170 GWh in the Brussels Region and 2.7 TWh offshore.[8] Total electricity generation in 2017 was 80.29 TWh (Figure 1).[7]

According to the World Bank, 100 per cent of the Belgian population has access to electricity.[9] The Belgian grid is well developed and the main challenge nowadays is its management to integrate variable and decentralized energy production. Phasing out from the nuclear production is planned in 2025. An energy pact to provide a look at the 2050 horizon and guarantee the electricity supply has been agreed on in April, 2018 between the federal government and the Regions.

In 1999 Belgium has implemented the European Directive concerning the internal electricity market to organise the unbundling of the roles in the electricity market (production, transport, distribution, supply, regulation, etc.) and progressive privatization.[10] The CREG (Commission de Régulation de l'Electricité et du Gaz) on the federal level and three regional entities act as regulators of the electricity and gas markets. They also control the distribution tariffs. In December 2017, the electricity for private use cost 0.264 EUR/kWh with small differences between Regions due to price differences for the distribution system operators.[11]

Figure 1.
Annual electricity generation by source in Belgium (TWh)

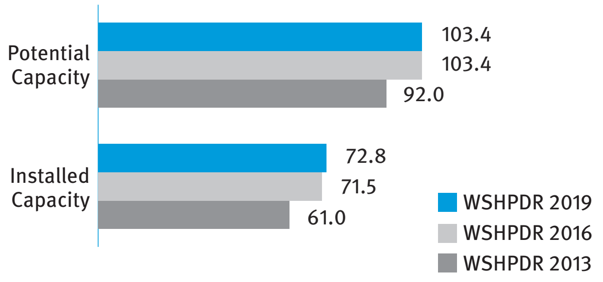


Source: FEBEG[7]

Small hydropower sector overview

Belgium's definition of small hydropower is hydropower plants with up to 10 MW. The installed capacity of small hydropower in Belgium is 72.8 MW while the economic potential is estimated to be 103.4 MW, indicating that more than 70 per cent has been developed (Figure 2).[12]

Figure 2.
Small hydropower capacities 2013/2016/2019 in Belgium (MW)



Source: *WSHPDR 2013*,[22] *WSHPDR 2016*,[23] APERe[12]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

The change in installed capacity is due to refurbishment of one of the 10 MW plants (Lixhe), where capacity was reduced by 7 MW with increased efficiency in order to maintain production levels. A second refurbishment reduced the capacity of the Andenne small hydropower plant by 1.9 MW. Another 7 MW were installed on navigable waterways (Canal Albert, Meuse and Sambre rivers), a total of six plants. The remaining differences are due to very small installations or refurbishments (below 100 kW).[12]

Belgium has only two plants above 10 MW capacity (33.765 MW or 31 per cent of the total installed hydropower capacity, a major refurbishment occurred in 2014, diminishing installed capacity). The total capacity of hydropower installed in Belgium in 2017 was 109.4 MW from 154 sites, which produced 240.1 GWh in 2017 (approximately 30 per cent below average due to a dry year).[5,8,12] In 2015, production accounted for 0.39 per cent for total hydropower and 0.24 per cent for the small hydropower of the final electricity consumption. Most of the sites (91 per cent in terms of number, 97 per cent in terms of capacity) are installed in the southern part of Belgium, in the Walloon Region. More than three quarters of installed capacity are on navigable waterways.[12] The main remaining potential is situated on navigable waterways in the Walloon Region. The regional government and its management entity SOFICO have adopted the decision to concede for private operation (20 years) 21 public sites on the rivers Meuse, Sambre and Ourthe, for a total of 50 GWh of increased annual production by 2025.[13] These sites have smaller heads (2 to 3 meters) than sites that have been historically exploited on navigable waterways. For a long time, it constituted a challenge to find economically viable technical solution for these sites.

Belgium also has a strong history of hydropower exploitation on non-navigable waterways before and during the industrialisation period. More than 2,500 sites of old mills or factories driven by the strength of water have been identified.[14] Part of these historical heads can be equipped, for an estimated increased annual production of 2.4 GWh by 2020 and 4.8 GWh by 2030.[15] Most of these sites are in the private domain, with private investment for refurbishment. The development of citizen cooperatives for the investment in the refurbishment of small sites is progressing. Revamping of historical sites currently in operation is expected to bring a capacity gain of 5 per cent, which corresponds to 18 GWh of increased annual production by 2030.[16] Depending on the age of the installations, revamping will be undertaken progressively in the next 10 to 15 years. All in all, at the 2030 horizon, the annual production of 470 GWh could be reached (economic potential).

The Walloon government and the electricity and gas regulator CWaPE (Commission Wallonne pour l'Energie) has been revising the supporting mechanism for new hydropower projects through the green certificates. The aim is to reach an Internal Rate of Return for the projects of 7 per cent after tax. [17] Moreover, the public investment aid in Wallonia (up to 20 per cent of the total cost) also allows, since December 2014, for eligibility of environmental investments (fish passes for a cost of maximum 35 per cent of the total investment).[18] Since environmental investments such as fish passes constitute an economic barrier to the projects, this change in regulation brings new opportunities for SHP developments.

Although Belgium's hydropower potential is already well exploited, the economic incentives put in place and the equipment programme of the navigable waterways are expected to bring the sector even closer to its potential.

Renewable energy policy

Belgium uses a tradable green certificate (TGC) system as its primary support mechanism for the deployment of renewable power technologies. There are four different TGCs (i.e. federal, Flemish, Walloon and Brussels green certificate) that vary in price and conditions.

The Federal Government is currently working on the energy pact to provide the country with a vision of its energy sector at the 2050 horizon. Each region is in charge to define the roadmaps to reach the regional targets for renewable energy production, in the frame of the 13 per cent of the final gross energy consumption national target for 2020. The actual roadmap for Wallonia specifies the targets of annual hydropower production of 420 GWh and 448 GWh by 2020 and 2024 respectively.[19] The Walloon government started to revise the roadmap for renewable energy development towards 2030 at the end of 2017.

Belgium is progressing towards its objective of 13 per cent of renewable energy in total energy consumption. A clear road map agreed by all regions is awaited to plan for the future years and beyond 2020.

Barriers to small hydropower development

Hydropower has historically been largely exploited in Belgium. In the Walloon Region, the equipment plan for navigable waterways and the revision of financial support for small hydropower development are expected to bring the sector even closer to its technical potential. Key challenges are:

- Higher environmental expectations regarding hydro morphology due to the implementation of the European Water Framework Directive;[20]
- Strict environmental conditions (ecological minimum flow, free fish migration up- and downstream, fish friendly turbines, etc.) are imposed on investors and sometimes jeopardize the technical or economic viability of the projects. A change in regulation to help clarify the environmental rules was expected in 2017 but has still not materialized.[21]

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4.4.3 France

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Key facts

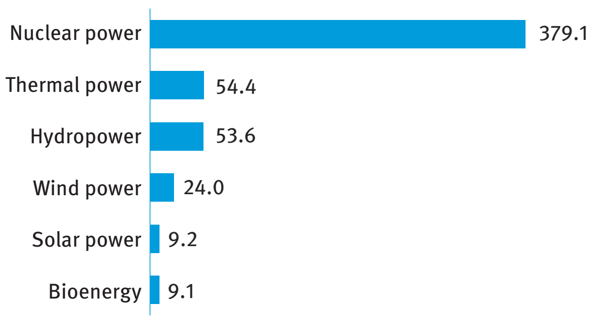
Population	67,118,650 [1]
Area	549,000 km[2]
Climate	Three types of climate are found in France: oceanic (west), continental (central, east) and Mediterranean (south). Average temperatures in northern Brittany are 6 °C in winter and 16 °C in summer. Paris averages a yearly temperature of 11 °C. The southern coastal city of Nice experiences an annual average of 15 °C.[2,8]
Topography	The topography of France includes mostly flat plains or gently rolling hills in north and west. The remainder is mountainous, particularly the Pyrenees in the south and the Alps in the east. The country's highest point is Mont Blanc at 4,807 metres.[2,8]
Rain pattern	Annual precipitation ranges from 680 mm in the central and southern region to 1,000 mm around Paris and Bordeaux. In the northern coastal and mountainous areas precipitation can reach 1,120 mm or more.[2,8]
Hydrology	Five major rivers create the drainage system of France. The Seine (780 km) flows through the Paris Basin and has three tributaries, the Yonne, Marne, and Oise Rivers. It drains into the English Channel. The Loire (1,020 km) is the longest river in France and flows through the central region. The Garonne is the shortest of France's major rivers. It rises in the Pyrenees, across the border with Spain, and empties into the Bay of Biscay at Bordeaux. The Rhône is the largest and most complex of French rivers. Rising in Switzerland, it flows southward through France for 521 kilometres, emptying into the Mediterranean. Lastly, the Rhine flows along the eastern border for about 190 kilometres (118 miles), fed by Alpine streams.[2,8]

Electricity sector overview

The total installed capacity in France at the end of 2017 was 130,761 MW.[3] Approximately 48 per cent of the total installed capacity came from the nuclear energy. Hydropower capacity was 20 per cent of the total installed capacity, while fossil fuel-fired thermal capacity represented 15 per cent. The total wind power capacity was approximately 11 per cent, and the total solar energy capacity was near 6 per cent. Net electricity generation for 2017 was 529.4 TWh.[3] Figure 1 offers more information on the electricity generation by source in France.

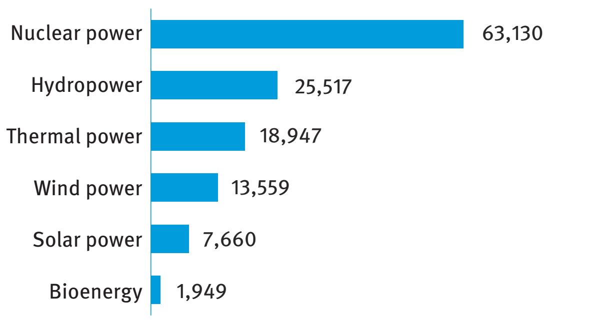
The Ministry of Ecological and Solidarity Transition is in charge of regulating energy matters. The electricity grid is owned and operated by Réseau de Transport d'Électricité (RTE). The French electricity market is open. However, it remains largely dominated by the formerly state-owned *Électricité* de France (EDF). EDF had an installed capacity of 98,237 MW at the end of 2014 (76 per cent of the total installed capacity of France). The electrification rate of the country is 100 per cent.[4,8]

Figure 1.
Annual electricity generation by source in France (TWh)



Source: The Ministry of Ecological and Solidarity Transition[3]

Figure 2.
Installed electricity capacity by source in France (MW)

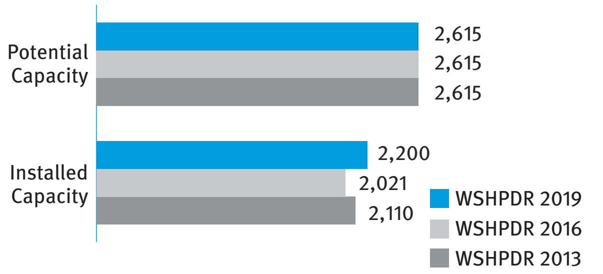


Source: RTE[5]

Small hydropower sector overview

In France, small hydropower (SHP) is defined as plants having an installed capacity up to 10 MW. The SHP installed capacity is 2,200 MW, and the production potential is between 2.7 and 3.7 TWh in addition to the approximate 7 TWh already generated. The total production of SHP represents roughly 10 per cent of the hydropower generation in France.[6,9,10] Small hydropower potential remains unchanged from previous reports, as no recent information was made available. According to the 2016 updates, France issued small hydropower tenders, aiming to increase the existent capacity by 60 MW.[11] In 2015, France already had 2,065 MW small hydropower installed capacity. The exact numbers were made available only in a 2017 national report. It is estimated that the existent stations produced 5,735 GWh of electricity in 2015.[10]

Figure 3.
Small hydropower capacities 2013/2016/2019 in France (MW)



Source: *WSHPDR 2013*,[7] *WSHPDR 2016*,[8] RTE,[9] EurObserv'ER[10]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

A commitment agreement for the development of sustainable hydropower in compliance with the aquatic environment restoration requirements was signed in June 2010 to promote hydropower if deemed suitable considering the environmental specifications. A part of the agreement directly concerns the equipment of existing weirs. The methodology and the "suitable conditions" to build a power plant onto existing weirs need to be made more detailed. A guidebook Towards the Hydroelectric Plant of the 21st Century for the development of SHP plants with regards to the natural environment is available.[10] It defines standards for the conception of a highly environmental quality plant. This guide is recognized and disseminated by national administrations.[8]

The French water administration drafted an inventory of obstacles in rivers, and aims to assess the degree to which those obstacles block the movement of species and sediment. A database was created in May 2012, including more than 60,000 obstacles such as dams, locks, weirs, and mills no longer in operation. A protocol called "Informations sur la continuité écologique" (ICE) has been also created to measure the capacity of obstruction of these obstacles. This vast project, brings together a large number of partners, identifies the installations causing the greatest problems and makes it possible to set priorities for corrective action. It will be also a good tool to identify new potential sites for SHP.[8]

Renewable energy plays an increasingly important role in meeting energy needs and hydropower remains the leading source of renewable electricity in France. The Multiannual Energy Programme (Programmation Pluriannuelle de l'Energie - PPE) published on October 2016 sets the goal of increasing hydropower installed capacity from 500 MW to 750 MW by 2023. Therefore, the Ministry launched the first call for projects for the development of small hydropower in April 2016 in order to promote the construction of new green fields and upgrade the equipment of existing dams. The 19 winners of this first call for projects, representing a capacity of 27 MW, were announced on April 2017. To continue this dynamic initiative, the Ministry announced in April 2017 a new call for tenders for 105 MW of new small hydropower plants, divided into three application periods of 35 MW.[11]

Renewable energy policy

A regional plan for climate, air and energy (Schéma régional du climat de l'air et de l'énergie, SRCAE), was jointly developed by the State and regional authorities. In particular, for 2020 and based on geographical area, this plan defines qualitative and quantitative regional targets for the valorisation of potential territorial renewable energy. In practice, this means identifying all sources for the production of renewable energies and of energy savings according to socio-economic and environmental criteria, and defining, in association with the local stakeholders (infra-regional authorities, companies and citizens), the level of regional contribution in achieving the targets set by France. This plan represents a strategic planning tool to guide the activities of local and regional authorities.[6] SRCAE is in progress.[8]

SRCAE, for hydropower potential, is based on data of producers and compatibility with lists of no-go rivers and restoration of river continuity priorities. France was the second largest producer of renewable energy in the EU in 2012. The country's strong points are hydropower, biofuels, and geothermal energy used in heating networks. France has the potential to achieve important targets in the renewable energy production. The 2012 share of renewable energy in France amounted to 13.7 per cent, and the target for 2020 has been defined as 23 per cent.[8]

In August 2015, the Energy Transition Law was promulgated. This law set the framework for the energy transition towards a greener and cleaner energy.[8]

Legislation on small hydropower

The maximum duration of permits is 75 years for big concessions. For relicensing, the duration is 20 years if there is no particular investment, and around 30 to 40 years if there is a significant investment. France has a lot of perpetual old permits for former mills subjected to new environmental restrictions. The Government's priority is simplification of the legislation, and some measures such as "Unique Authorization" are under review. The idea is to merge the different authorizations into one category in order to accelerate the process and relieve the administrative burden.[8]

Residual flow regulation exists, i.e. 10 per cent of interannual average flow, and for modules over 80 m^3/s, 5 per cent is admissible.[8] While the minimum (10 or 5 per cent) is set by the law, the adapted minimum ecological flow is set case by case through environmental assessments. The most used method is the microhabitat method (using EVHA software), but there are other possible methods adopted when EVHA does not suit the type of river. Since 1984, the reserved flow was around 10 per cent of the average annual flow. Since 2006, 10 per cent is the minimum, and local administrators often ask for more (12 to 17 per cent), without any justification on improvement or maintenance of the ecological status. In periods of extreme low water levels, the Préfet, head of the Department (French subdivision) can decide to lower temporarily the residual flow.[8] Under the impetus of the European Commission, France enacted a new law on energy transition in order to comply with the new European State Aid Guidelines. A new tariff order was published in December 2016, the H16 contract, which sets out conditions for plants under 1 MW to access support mechanism. Plants under 500 kW can benefit from feed-in tariffs (FIT) (tariff H16) and plants between 500 kW and 1 MW can benefit from premium feed-in-tariffs (additional remuneration). This new support mechanism is a bonus paid monthly in addition to the sale of energy on the market. Purchase prices are between 0.11 and 0.13 EUR/kW. Finally, a tendering system is implemented for plants above 1 MW.

Barriers to small hydropower development

There are multiple barriers to small hydropower development in France. Some of the main barriers are outlined below.

- The classification of rivers carried out by the Government in 2012 states that no more new works (no hydropower plant among other) can be created on the rivers ranked in List 1 which impacts more than 71 per cent of the hydropower potential. This classification also implies for the owners of hydropower plants located on rivers ranked in List 2 to carry out heavy and expensive installations to ensure the transport of the sediments and the circulation of migratory fishes.
- Costs related to the environmental development are becoming increasingly burdensome for producers, representing investments in the range of several times the turnover of a plant.
- There are numerous financial obstacles to SHP development. French producers who cannot, or do not wish to, invest to benefit from new FIT contract have to sell their production directly on the market. The market price does not take into account specificities of the SHP production (i.e. the green value and the decentralized production. The market price level of small hydropower electricity generation (around 40 EUR/MWh in 2017) does not allow any investment and may push some small units into bankruptcy. The industry has also alerted the authorities about the inflation of the local taxation which can weigh up to 10 EUR/MWh, meaning 1/4 of the purchase price of electricity on the market.[3,8]

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4.4.4 Germany

Mathis Rogner, International Hydropower Association (IHA)

Key facts

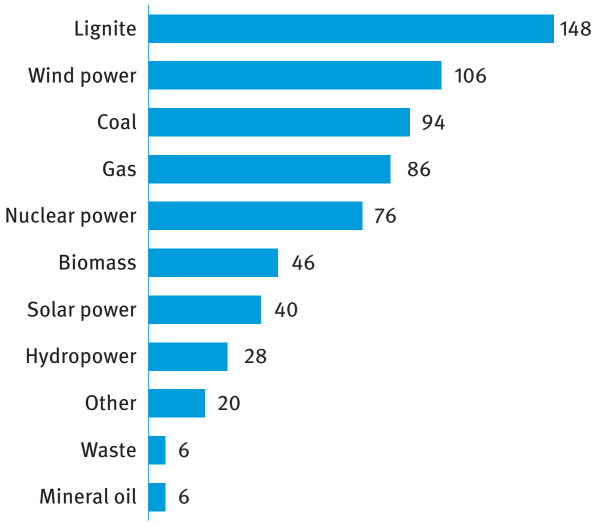
Population	82,740,900 [1]
Area	357,380 km²[2]
Climate	Germany's north-western and coastal areas are classified by a maritime-influenced climate with warm summers and mild winters. The climate transitions to a continental climate to the south east, with greater seasonal variations in winter and summer. Germany's Alpine regions exhibit lower temperatures and higher precipitation. Historically, the mean temperature in winter (December – February) is 0.9°C and in summer (June – August) 16.3 °C. Extreme temperatures can reach from -10 °C to 35 °C.[3] Occasionally there is warm mountain wind (föhn).
Topography	The northern areas are characterized by coasts and lowlands, while the centre is mainly covered by forested uplands. Low mountains in the south-west merge with the Bavarian Alps in the south-east, which form the border with Austria and Switzerland, with the highest altitude at Zugspitze peak (2,963 metres). The country's lowest point is 3.5 metres below sea level. [3]
Rain pattern	Average annual precipitation is 789 mm. The amount of rainfall decreases across the country from west to east, with markedly higher precipitation in the Southern mountainous regions.[4]
Hydrology	Germany is rich in water resources, with 2.2 per cent of its surface area covered by water, of which 40 per cent are natural lakes. The country is traversed by major European rivers such as the Rhine, Elbe, Saale, Neckar, Weser, Oder and Danube. The main flow direction of rivers is from the southern Alpine region and central mean range mountains to the north (Rhine, Elbe, Weser) and to the east (Danube River).[10] The country's largest lake is Lake Constance (Bodensee), which is shared with Austria and Switzerland.

Electricity sector overview

The German power system is the largest in Europe. In 2017, the country's installed electricity generating capacity totalled 207.9 GW, with renewable power sources making up approximately 50 per cent (104.5 GW).[13] The gross power production in Germany in 2017 was 654 TWh, where renewables contributed approximately 36.2 per cent (218 TWh).[13]

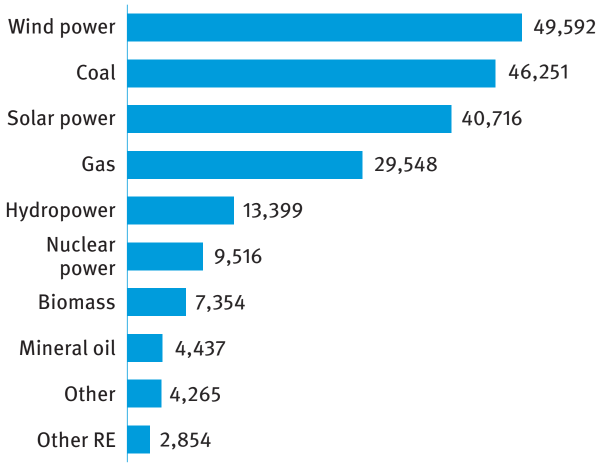
Power generation in the German electricity market is currently dominated by four incumbent power generators that share the market with a small number of regional and hundreds of municipal utilities. With the liberalisation of the electricity market in 1998 and dedicated policies focused on ushering in the Energiewende, a number of independent power producers have entered the market, especially operating small-scale wind and solar PV facilities, reflecting a trend towards increasing decentralised power generation. Following European Commission legislation mandating a legal unbundling of network businesses in 1996, the four incumbent transmission companies became legally independent from their parent generator companies. Distribution networks are owned and operated by more than 800 regional and local operators. The rate of electrification in Germany is 100 per cent.

Figure 1.
Annual electricity generation by source in Germany (TWh)



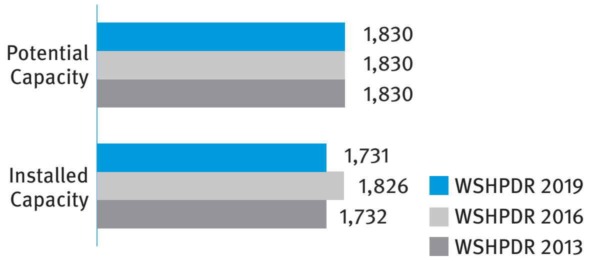
Source: Federal Ministry for Economic Affairs and Energy[13]

Figure 2.
Installed electricity capacity by source in Germany (MW)



Source: Federal Ministry for Economic Affairs and Energy[13]

Figure 3.
Small hydropower capacities 2013/2016/2019 in Germany (MW)



Source: *WSHPDR 2013,*[14] *WSHPDR 2016,*[15] Bundesnetzagentur für Elektrizität[16]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019.*

Germany's energy policy is predominately driven by the Energiewende, seeking the gradual phase-out of nuclear power while concurrently reducing greenhouse gas emissions through increased renewable energy production and energy efficiency improvements. Long-term goals plan for 80 per cent of electricity demand to be met by the renewable generation by 2050, compared to the current average rate of 35 per cent.

As a result of dedicated policies and investment, Germany has experienced a remarkably rapid increase of renewable energy over two decades. However, the continued growth of renewables and stability of the power grid hinges on the expansion and improvement of the power grid, including both large-scale north-south transmission lines, but also upgraded low and medium distribution grids that can incorporate increased decentralised generators, energy storage, and new smart technology and electric vehicles.

German power prices are among the highest in the European region. Despite wholesale electricity prices declining on average over the past decade, additional politically determined surcharges and taxes, as well as grid fees have, in general, increased electricity bills for households. Only 21 per cent of the power prices is set by the market.[5] Electricity prices at the end of 2017 were 0.30 EUR/kWh (0.35 US$/kWh) for household consumers, and 0.15 EUR/kWh (0.18 US$/kWh) for non-households.[6]

Small hydropower sector overview

Historically, Germany has been a global leader in developing, installing and operating hydropower plants for over 100 years. The Germany Ministry for Economic Affairs and Energy recognises that no international consensus on the definition of small hydropower currently exists. Despite accepting that definitions across Europe place the limit of small hydropower at 10 MW, the definition of small hydropower in Germany applies to projects up to and including 1 MW installed capacity.[7]

According to confirmed SHP data published in 2018 by the Bundesnetzagentur (the Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway), installed capacity in Germany amounted to 1,730.8 MW in 2016.[16]

The vast majority of German hydropower plants are less than 10 MW. Germany does not have a national centralized register for small hydropower projects, as many micro- and pico-hydropower projects used for self-consumption are difficult to identify.[8] Based on reports from the regional Transmission Service Operators, the country has an estimated 7,249 operational hydropower projects, of which a 7,110 have less than 10 MW installed capacity. It is likely, however, that there could be a further 300-400 very small projects in operation.[8] An estimated 6,900 projects have capacities less than 1 MW, where nearly 80 per cent have less than 100 kW installed capacity.

The majority of small hydropower projects are located in the mountainous southern provinces, with 50 per cent of all projects located in Bavaria and 20 per cent in Baden-Württemburg. These two states typically account for over 80 per cent of annual German hydropower production. Hydropower production can fluctuate year-on-year by 10-15 per cent depending on precipitation and river flows.[17]

Renewable energy policy

Feed-in electricity tariffs (FITs) were introduced as part of the Renewable Energies Act (EEG) in 2000 as a measure to incentivise renewable energy deployment and production, and apply also to hydropower. The FIT system has been amended several times. In 2014, the system was amended to be applicable only to small institutions. Most recently with the revision of the EEG in 2017, auctions became the standard process for the determination of tariffs which were previously fixed by governments. However, hydropower remains excluded from the auctioning system.[9]

The duration of a FIT is 20 years, while the tariffs are revised every four years. The FIT is set to:

- 12.52 EUR cents/kWh (14.66 US$ cents/kWh) ≤ 500 kW;
- 8.17 EUR cents/kWh (9,56 US$ cents/kWh) ≤ 2 MW;
- 6.25 EUR cents/kWh (7,32 US$ cents/kWh) ≤ 5 MW;
- 5.48 EUR cents/kWh (6,42 US$ cents/kWh) ≤ 10 MW;
- 5.29 EUR cents/kWh (9.19 US$ cents/kWh) ≤ 20 MW.

The revised EEG maintains the additional regulations on annual decreases (0.5 per cent) and on the fulfilment of the environmental protection standards.

Small hydropower development is regulated by a number of European, Federal and State legislation. Federal legislation concerning environmental impacts, biodiversity, greenhouse gas emissions, and renewable energy have all been formed or recently amended to adhere with the European Directives such as the Water Framework Directive, Habitats Directive, and the Environmental Impact Assessment Directive.

Most importantly for small hydropower in Germany is the Federal Water Resources Law or Wasserhaushaltsgesetz (WHG). Particularly relevant are the regulations that govern the damming, abstraction or diversion of river flows, which are only permitted if minimal environmental flows can be ensured. Any new dam infrastructure or change to operations must maintain or improve the quality of the water. For hydropower specifically, greenfield projects are only permitted when appropriate steps to preserve fish populations are implemented.[10] In Germany, the regulation and approval of hydropower projects is responsibility of the state authorities to interpret and apply federal legislation.

Thus, small hydropower potential is limited in Germany, especially for new greenfield projects. However, significant potential exists in modernising, upgrading or restarting existing small hydropower sites. Previous studies from 2015 reviewed remaining hydropower potential, taking into account economic and regulatory constraints, and estimated it to be 1,123 MW, 70 per cent of which is concentrated in Bavaria and Baden-Württemburg.[11]

Barriers to small hydropower development

The development of small hydropower plants in Germany faces barriers of different types, related to complex licensing procedures:[18]

- Existing plants: licensing is based on the assessment of the possible impact on stream ecology. This is valid for the optimization or the reactivation of already existing hydropower plants.
- New plants: new sites are licensed only after approval procedure that requires thorough assessments of environmental concerns with respect of European, national and federal legislations. Few entirely new projects on suitable sites are realized.
- New potential sites: expensive assessments are required to avoid any undesired impact on stream ecological systems. The required hydraulic structures and operation modes are usually expensive.

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4.4.5 Luxembourg

International Center on Small Hydro Power (ICSHP)

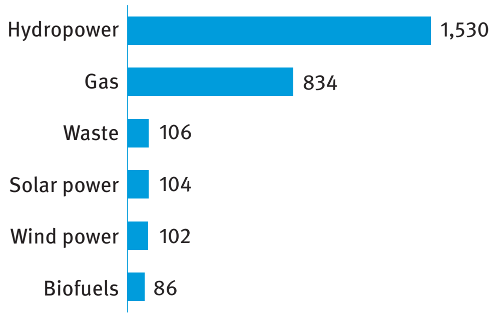
Key facts

Population	602,005[1]
Area	2,586 km[2]
Climate	The climate is mild with no dry seasons, typical for marine countries in the western part of Europe. The annual average temperature is 8.5 °C. In the winter, temperatures reach on average 3.3 °C during the day and -1.8 °C at night. Average high temperatures in the summer reach 21 °C, with lows of roughly 11.3 °C. The summers are thus generally cool and winters mild in Luxembourg.[2]
Topography	Luxembourg is a landlocked country, characterised by low mountains and rolling hills covered in green, dense forests. The highest point of the country is the peak Burgplatz, which reaches 559 metres. The southern region of Gotland has fertile lands and nourishing rivers. In contrast, the northern region of the country is a rigid plateau, with arid soil.[3]
Rain pattern	Annual rainfall was approximated at 833 mm in 2017. From 2007 to 2017 average annual rainfall was calculated to be 779 mm. The highest annual rainfall was in 2014, estimated at 891 mm, and the lowest was in 2011, at roughly 544 mm.[4]
Hydrology	The Moselle is Luxembourg's lowest point, at only 133 meters above sea level, and one of the most important rivers of the country. The Sûre and the Our are other major rivers and form the border with Germany. In the southern region, the Alzette river flows towards the north, until it reaches the Sûre river.[5]

Electricity sector overview

In 2015, total electricity generation was 2,762 GWh, lower than 2013 generation by approximately 3 per cent. Hydropower accounted for roughly 55 per cent of the produced electricity. Over 70 per cent of the electricity was generated from renewable energy sources.[6] In 2016, Luxembourg imported 7,718 GWh electricity and exported 1,420 GWh. Population gross demand for electricity was estimated at 8,489 GWh.[7] Figure 1 below offers more details on electricity generation by source in Luxembourg.

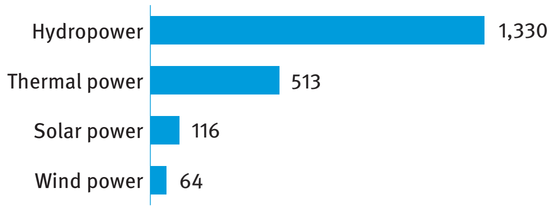
Figure 1.
Annual electricity generation by source in Luxembourg (GWh)



Source: IEA[6]

Total installed capacity of electric power plants was at least 2,023 MW at the end of 2015.[8] The country is highly dependent on electricity imports and therefore its energy sector policies are affected by the markets in the surrounding states. According to European Union (EU) statistics, Luxembourg was also one of the lowest electricity consumers among the EU member states. The electrification rate is 100 per cent.[9] Figure 2 below showcases the installed capacity by source in Luxembourg. Hydropower, solar and wind power plants account for roughly 75 per cent of the overall installed capacity. No data was made available so far with regards to installed biofuels and waste capacity.[8]

Figure 2.
Installed electricity capacity by source in Luxembourg (MW)



Source: UN[8]

The largest share of electricity generated in Luxembourg comes from the Viaden pumped-storage hydropower plant, which accounted for 1,422 GWh in 2016. Hydropower plant Moselle-Sûre generated 99 GWh in the same year and small private plants produced an estimated 8 GWh.[10] There are multiple electricity suppliers in Luxembourg – Eida, Electris, Enovos, Leo, Nordenergie, Steinergy, Sudgaz and Sudstroum. The main provider of electricity is Enovos, however certain municipalities might use specific private electricity suppliers. Creos is the division conducting pipe maintenance and is in charge of the electricity and gas distribution. Enovos resulted from the 2009 merger of three historic players in the Luxembourg energy market: Cegedel, Soteg, and Saar Ferngas. Creos is a subsidiary of Enovos.[11]

According to report from the Luxembourg Institute of Regulation, Enovos had 75 per cent market share in the electricity retail market and 59.5 per cent in the professional segment. LEO, an important player in the country's energy market, is another subsidiary of Enovos Luxembourg and has market shares of 13 per cent and 27.6 per cent, respectively. The main shareholder in Enovos is the Grand-Ducal State, therefore most of the shares are owned by the Government of Luxembourg.[11] Table 1 below offers more details with regards to which institution owns shares in Enovos.

Table 1.
Enovos shareholders in 2017 (%)

Shareholder	*Ownership (%)*
Etat Grand-Ducal (The Grand Ducal State)	25.44
Ardian	23.48
RWE Energy	18.36
SNCI	10.01
E.ON	10.00
Administation communale de la Ville du Luxembourg	8.00
GDF Suez (Electrabel)	4.71

Source: Electricite Luxembourg[11]

Table 2 provides information on tariffs in 2017, based on provider. The integrated price takes into account network usage fees and the price of electricity. On the other hand, it does not include VAT, counting and legal fees.

Table 2.
Electricity tariffs by provider in Luxembourg (US$/kWh)

Provider	*Network usage price US$/kWh*	*Electricity price*		*Integrated price*	
		Day (US$/kWh)	*Night (US$/kWh)*	*Day (US$/kWh)*	*Night (US$/kWh)*
Creos	0.071	0.072	0.047	0.143	0.120
Mersch	0.081	0.072	0.047	0.153	0.130
Esch/Alzette	0.078	0.072	0.047	0.150	0.125

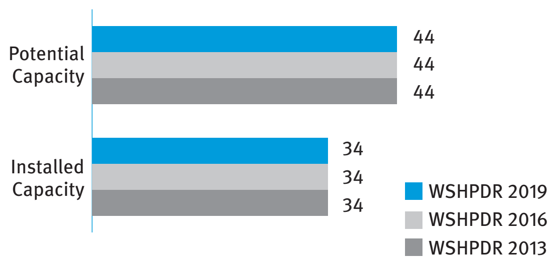
Source: Electricite Luxembourg[11]

In addition, Enovos also offers a "green.connect" scheme, which clients can benefit from online. The scheme offers better tariffs for electricity produced from renewable energy sources, encouraging the dissemination of renewables plants in Luxembourg.

Small hydropower sector overview

Luxembourg small hydropower (SHP) definition refers to plants up to 10 MW. At the end of 2016, the installed SHP capacity of the country was 34 MW. This amount has not changed in the past five years, remaining constant. Statistics show that small hydropower gross production decreased in Luxembourg, only reaching 115 GWh in 2016. The decrease in national small hydropower production might be explained by Luxembourg's increasing dependence on imports from its neighbours.[12,13] Soler is one of the main renewable energy companies in the region, currently operating several small hydropower plants in northern and eastern Luxembourg – the Rosport small hydropower plant, Ettelbruck and Esch-sur-Sure.[14] Figure 3 below provides information on the total installed SHP capacity in Luxembourg, as well as the estimated potential capacity. Statistics remain constant and there is no update from the Government of Luxembourg or from private owners. Both the public and the private sector will conduct future feasibility studies and thus plan further dissemination of SHP. There is no specific information with regards to small hydropower potential in the country. However, according to the 2020 target, at least 10 more MW should be developed.[13]

Figure 3.
Small hydropower capacities 2013/2016/2019 in Luxembourg (MW)



Source: *WSHPDR 2013*,[15] *WSHPDR 2016*,[13] STATISTA,[12] Soler[14]

Note: The comparison is between data from *WSHPDR 2013, WSHPDR 2016* and *WSHPDR 2019.*

According to Soler latest updates, the company under the joint leadership of SEO and Enovos, the Rosport small hydropower plant must reach a good ecological status to fulfil the requirements of the European Water Framework Directive. To achieve the aforementioned status, the minimum flow must be considerably increased. The Luxembourg State will install a wastewater turbine near the existing dam to enhance minimum flow. The Rosport small hydropower plant is located on the dam of the Sûre, in Rosport Ralingen. The plant is equipped with two vertical Kaplan turbines and its installed capacity is 6.5 MW. Rosport plant produces roughly 24 GWh per year.[14] The Ettelbruck power plant is located on the Alzette and generates 0.82 GWh per year. The installed capacity of the power plant is 200 kW. Ettelbruck was completely renovated in 1998 and operates today without any personnel, monitored remotely from Esch-sur- Sûre.[14]

In contrast to Ettelbruck and Rosport plants, the Esch-sur-Sûre is not a run-of-the-river power station, but a storage power station for peak power generation. The plant was built in 1950, at the same time as the artificial lake and its auxiliary dams. It comprises two vertical Francis turbines with a capacity of 5.5 MW each. To ensure constant flow of water, the plant has four auxiliary dams. Dams 1 to 3 have 2 Kaplan turbines with a capacity of 250 kW each. Dam 4 has a turbine with a capacity of 300 kW. The plant produces 18 GWh annually.[14] Table 3 below offers more detailed information on 26 out of the 33 small hydropower plants in Luxembourg. Unfortunately, a complete list of SHP plants is not yet available.[16]

Table 3.
List of small hydropower plants in Luxembourg

Site	*Plant size (kW)*	*River*
Ettelbruck	250	Alzette
Clouterie/Bissen	140	Attert
Moestroff	140	Sûre
Birtrange	105	Alzette
Cruchten	105	Alzette
Essingen	93	Alzette
Erpeldange	85	Sûre
Bounsmuhle	60	Syr
Bettendorf	50	Sûre
Bigonville	48.5	Sûre
Steckenmuhle	48	Syr
Bissermuhle	45	Attert
Felsmuhle	45	Syr
Stolzemburg	45	Our
Useldingen	45	Attert
Bannmuhle	40	Attert
Fausermuhle	40	Syr
Bourscheid	35	Sûre
Fockenmuhle	30	Eisch
Schuttburg	26	Clerf
Hessenmuhle	22	Weiβe Ernz
Neumuhle	15	Weiβe Ernz
Reisermuhle	15	Weiβe Ernz
Tuchfabrik/Bettborn	15	Roudbaach
Maulusmuhle	11	Woltz
Backesmuhle	10	Weiβe Ernz
Total	**1,563.5**	

Source: Industrie Luxembourg[16]

Feed-in tariffs are available for plants between 0.5 MW and 10 MW. The initial regulation on renewable energy was amended in 2005, feed-in tariffs for electricity produced from renewable energy being established. Table 4 below shows the feed-in tariff rates for small hydropower plants. [17]

Table 4.
Feed-in tariffs for small hydropower in Luxembourg

Plant size	*FIT (EUR per kWh)*
0.5 MW to 3 MW	0.0628 (0.074)
3 MW to 10 MW	0.0541 (0.064)

Source: IEA[17]

In August 2014, there were updates in the current laws with regards to feed-in tariffs policies for all renewable energy sources, including small hydropower. The new regulations take into consideration the investment aids from other entities.[18]

Renewable energy policy

Luxembourg's renewable energy target is to reach 11 per cent of the final energy consumption share by 2020, according to the National Renewable Energy Action Plan (NREAP). Its current share is 5 per cent, therefore the country would need to at least double its renewable energy consumption share.[13,19] On 26th October 2017, an agreement was signed between Luxembourg and Lithuania on the statistical transfer of renewable energy amounts, taking into account the stipulations in the Renewable Energy Directive. The European Commission has shown tremendous support to the aforementioned initiative, as it will assist Luxembourg in achieving its national renewable energy target by 2020. The agreement specifies that Lithuania will transfer a certain amount of renewable energy between 2018 and 2020 to help Luxembourg reach its target. Statistical transfers were accepted by the European Union (EU) in 2009, as a possibility to efficiently reach renewable energy national targets of member states and encourage further collaboration in the sector.[19]

The national 2020 target also specifies that 8.5 per cent of heating and cooling will be from renewable energy sources. Renewables share in the transport sector will also reach 10 per cent and they will account for 11.8 per cent of the total electricity production.[20] The Government of Luxembourg currently offers diverse feed-in tariffs schemes for the following technologies:

- Biogas;
- Hydropower;
- Old and scrap wood;
- Photovoltaic;
- Sewerage gas;
- Solid biomass;
- Wind energy.[20]

Luxembourg's limited land area and its lack of access to major water resources prevent the country from achieving higher shares of renewable energy. Its current target is considered to be one of the smallest in the European Union.[13] The country's dependence on electricity imports might also partly justify why its renewable energy policies are condensed.

Barriers to small hydropower development

There are multiple barriers to small hydropower in Luxembourg. Some of the most relevant are outlined below.

- The country's energy needs are mostly imported at present, Luxembourg strongly relying on its neighbours with regards to electricity produced through small hydropower and other renewables. Therefore, as long as such partnerships flourish, there is no motivation to implement or approve construction of future projects.
- There are no well-defined priorities with regards to an energy strategy after 2020.
- There is low small hydropower potential in Luxembourg, as a limited number of sites are available for construction of SHP plants.
- The country's research and development policies focus on clean energy technologies, but not specifically on small hydropower – there is higher interest in solar and wind power technology development.
- A lack of feasibility studies in the sector makes it difficult to determine the true small hydropower potential.[21]

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4.4.6

The Netherlands

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Key facts

Population	17,205,123 [1]
Area	41,543 km^2
Climate	The Netherlands have a moderate maritime climate with typically high levels of humidity of between 75 and 90 per cent. Summers are cool with a monthly average temperature of 23 ºC and winters are mild with a monthly average temperature of 0 ºC.[2]
Topography	The Netherlands mostly consist of a coastal lowland and reclaimed land (polders), with some hills in the south-east. The highest point, the Vaalserberg, is 323 metres above sea level. Twenty-six per cent of the area and 21 per cent of the population are located below sea level as a result of peat extraction and land reclamation.[3]
Rain pattern	Precipitation is distributed relatively evenly throughout the year (50-90 mm/month). Average annual precipitation is 847 mm.[2]
Hydrology	The major rivers of the Netherlands are the Rhine, flowing from Germany, and its several arms, such as the Waal and the Lower Rhine rivers, and the Maas (a branch of the Meuse) and the Schelde (Escaut), flowing from Belgium. These rivers and their arms form the delta with its many islands. Together with numerous canals, the rivers give ships access to the interior of Europe.[4]

Electricity sector overview

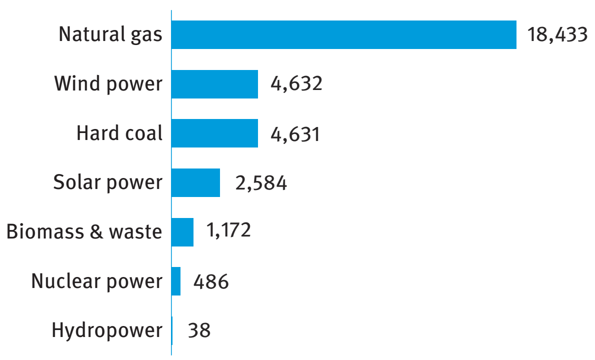
The Netherlands produced a total of 110.1 TWh of electricity in 2017, of which hydropower plants generated only 94 GWh.[5,18] Integrated into the North-West European electricity market, the Netherlands imported 30.8 TWh of electricity and exported 22 TWh, resulting in the total electricity supply of 118.9 GWh in 2017.[6] Renewable energy production has grown continuously, approximately by 1 per cent in recent years.

The Netherlands have approximately 31.98 GW of installed capacity and the energy mix is dominated by natural gas, wind and hard coal (Figure 1).[7] With the combined installed capacity of 38 MW, hydropower plants account for just 0.1 per cent of the total installed capacity. The country has a full electrification rate and grid availability is guaranteed in the whole country at a level of 99.99 percent.[8]

The Dutch electricity market was liberalized in 2004. Electricity is generated mainly by four large-scale companies – Essent, Nuon, EON and Engie. In addition, there are a relatively large number of small-scale decentralized generators. Under the Electricity Act (1988), the electricity distribution and transmission networks should be publicly managed and owned. As a result, the state-owned company TenneT is the only electricity transmission system operator.[9]

The average electricity tariff for households in the first half of 2017 was EUR 0.156 (US$ 0.192) per kWh, and EUR 0.082 (US$ 0.101) per kWh for non-household consumers.[17] With strong integration in the European electricity market, the energy price for the end consumer is dependent on the European price trends. The energy mix, predominantly natural gas, has benefitted from low gas prices, the low price of CO_2 emissions allowances, high production capacity in the Netherlands and low electricity prices in Germany. In the longer term, the prices of gas and coal are expected to increase, which combined with a decrease in overall capacity is expected to lead to an increase in the wholesale electricity price towards 2020. The increase in renewable electricity production, particularly after 2020, will have a mitigating impact on the wholesale prices. Over time, wind and solar power will increasingly replace gas and coal-fired plants that have higher marginal production costs. This will lead to a steadier average wholesale price after 2020, despite rising coal, gas and CO_2 prices.[10]

Figure 1.
Installed electricity capacity by source in the Netherlands (MW)

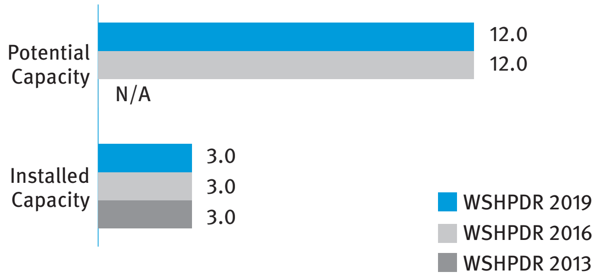


Source: ENTSO-E[7]

Small hydropower sector overview

The definition of small hydropower (SHP) in the Netherlands is up to 10 MW. The installed capacity of small hydropower is 3 MW while the potential capacity is estimated to be 12 MW, indicating that approximately 25 percent has been developed.[11] Compared to the *World Small Hydropower Development Report (WSHPDR) 2016*, the installed and potential capacities have not changed (Figure 2).

Figure 2.
Small hydropower capacities 2013/2016/2019 in the Netherlands (MW)



Source: ESHA,[11] WSHPDR 2013,[12] WSHPDR 2016[13]

Note: The comparison is between data from *WSHPDR 2013, WSHPDR 2016* and *WSHPDR 2019.*

The network of rivers covering the Netherlands is rather complex, with a large part of the country being located in the delta of Rhine-Meuse-Scheldt rivers. The country's topography is dominated by lowlands and reclaimed land (polders). A lot of water resources are available but due to the flat topography, hydropower potential is low. As a result, hydropower potential mostly derives from the existing water management works needed for flood control and navigation measures. Total installed hydropower capacity in the Netherlands is 38 MW and this is mostly produced with three power plants located on weirs used for navigation.[13]

With approximately 3 MW of installed capacity, small hydropower accounts for 8 per cent of total hydropower installed capacity and only a minor part of the country's total installed capacity (less than 0.01 per cent). The biggest SHP plant is Hagestein, with an installed capacity of 1.8 MW. The rest of the capacity is distributed among 16 other plants with installed capacities of less than 0.2 MW.[14] By 2020, the aim is to have a total of 25 plants generating 10 GWh of electricity annually.[11] To achieve this, many small watermills could be reactivated. The additional potential is found in the numerous sluices and weirs with heights between 1 and 3 metres, where low head turbines, as well as screw turbines, could be installed.[20]

In addition to the hydropower plants, the country has potential for tidal small hydropower to be installed on the coastal structures regulating water outflow and on the sea-flood protection structures. The turbines on barriers at Afsluitsijk (IJsselmeer) were installed in 2008 and are used for tidal turbine development and feed the Dutch grid. Since autumn 2015, the tidal turbines installed on the storm-surge barrier in Oosterschelde operated with a total capacity of up to 1.2 MW.[15]

Renewable energy policy

Under the European Union Renewable Energy Directive (Directive 2009/28/EC), the Government of the Netherlands committed to a target of 14 per cent of the country's final energy consumption to be from renewable energy sources by 2020, including at least 10 per cent of renewable energy in transport. Although the share of renewable energy sources in the country's energy mix has strongly increased in the last years, in 2016 only 6 per cent of energy used in the Netherlands came from renewable sources and renewable sources accounted for only 13 per cent of total electricity generation.[19] Based on a recent prognosis, the country will not be able to reach the target agreed by the European Union and in 2020 renewable sources will produce only 12.4 per cent of Dutch energy.[19] In order to boost the share of renewable energy sources and reduce carbon emissions by 2030, the Government plans to close all coal plants in the next decade and to build more wind farms in the North Sea.[19]

The production of renewable energy will be promoted with the following instruments:

- Sustainable Energy Incentive Scheme Plus (SDE+);
- Obligation to use biofuels in the transport sector;
- Co-firing with biomass in coal-fired power stations;
- Import of renewable energy.[6]

The growth should mainly be sourced from wind, biomass and solar photovoltaic. Hydropower is expected to account for less 1 one per cent of the total.

In most of Western Europe, energy producers are separated from the high-voltage grid. The grid operator does not distinguish between different electricity producers and is obligated by law to connect all parties to the grid and transmit electricity across the high-voltage grid. The energy sector regulator supervises the energy sector and ensures the conditions for a free energy market.

Small hydropower is mainly supported by the operating grant of the Stimulering Duurzame Energie (Encouraging Sustainable Energy Production, SDE) and the Energy Investment Allowance tax deduction. The SDE+ is available for the production of renewable electricity, renewable gas, renewable heat and the renewable combination of heat and electricity. The SDE offers long-term (15 years for hydropower) financial security by simulating unprofitable project components. The subsidy is the difference between a basic amount (cost price of the renewable energy) and the energy market price. The Dutch Government determines a maximum SDE+ budget for each year. This equates to first come first served principle, and the projects that tender in the first slot (with a lower subsidy) have the best chance to receive the subsidy. In the first of two slots in 2018, a total budget of EUR 6 billion (US$ 7.4 billion) is foreseen.[16]

For small hydropower plants with a height of less than 5 metres, the SDE provides a maximum of 0.13 EUR/kWh (0.15 US$/kWh) minus the energy market price for 5,700 hours. The SDE also foresees the subsidies for the refurbishment of the existing hydropower plants in a similar amount but with a lower working hours limitation (2,600 hours).[16]

Generally, produced energy has to feed into the local grid based on the market prices (0.04-0.05 EUR/kWh (0.05-0.06 US$/kWh) in 2017). In the case of a very small power plant with a grid connection of less than 3 x 80A, there is the possibility of net metering, meaning that produced energy could be deducted from the amount of total consumed energy. The small consumer energy price in the Netherlands is in the range of 0.22 EUR/kWh (approximately 0.25 US$/ kWh), comprised of EUR 0.06 of production costs, EUR 0.12 of energy tax and EUR 0.04 of VAT. Net metering provides the possibility to have the full consumer price instead of the feed-in price of 0.05 EUR/kWh. Net metering is only allowed if the power plant is located on one's own property.[16]

The Energy Investment Allowance tax deduction ensures that 44 per cent of the investment costs can be deducted from the taxable profit.

Barriers to small hydropower development

The main limitations for small hydropower development in the Netherlands are outlined below.

- Hydrological potential is low due to the flat relief.
- Local water communities ("Waterschappen") are reluctant to issue permits, although there are quite a few places where the development of small hydropower plants could be possible.
- The development of small hydropower is nearly halted due to the lobby of fishermen (recreational and professional). It is very difficult to obtain Waterwet (water law) and Natuurbeschermingswet (nature preservation law) permits, due to new fish mortality requirements. Debates in Parliament resulted in the requirement that small hydropower operators have to install fish guidance systems. A final decision fully in favour of nature and fishery protection measures might result in closing or decommissioning of most small hydropower plants in the Netherlands. In addition, the fishermen lobby's implementation of the Water Framework Directive complicates developments.[13]

It is therefore recommended to carry out a comprehensive study, using a geographic information system (GIS) based computer model in order to provide a clear estimate of the practical potential for expanding hydropower production, including small hydropower within the Netherlands.[13]

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4.4.7

Switzerland

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Key facts

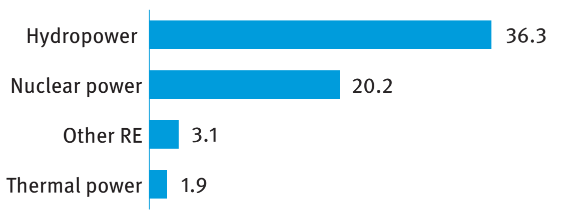
Population	8,419,550 [1]
Area	41,277 km[2]
Climate	Switzerland has a temperate climate, which varies with elevation and with location relative to the main alpine ridge. It has cold, cloudy, rainy/snowy winters, and cool to warm and occasionally hot humid summers, with frequent thunderstorms along the main alpine ridge.[2] Selected average temperatures vary from -10 to +9 °C (low) to -4 to +17 °C (high) across the country.
Topography	Switzerland is mostly mountainous, with the Alps in the south and Jura in the west/northwest, and a central plateau with large lakes. The highest summit is the Pointe Dufour/ Dufourspitze at El. 4,634 metres above sea level.
Rain pattern	Switzerland experiences frontal and orographic rainfall. Average precipitation is 2,000 mm/year in the northern foothills of the Alps, in the Alps and in southern Switzerland, about 1,000-1,500 mm/year in the lowlands north of the Alps and between 500 and 700 mm/year in Valais and Grisons regions. The amount of precipitation during the summer semester (defined as April-September) is nearly double that of the winter semester (except in the Canton of Valais). From an elevation of 1,200-1,500 metres above sea level, precipitation during winter usually occurs as snowfall.[2]
Hydrology	The share of precipitation available for runoff depends on evapotranspiration and temporal storage (as snow, ice or underground). In Switzerland, the potential evapotranspiration decreases with elevation going from the central plateau to the alpine areas, due to decreasing temperature and less intensive land use. Rivers exhibit a variety of runoff regimes, which mainly differ depending on the role played by snow and ice storage in the contributing catchment. Mountain rivers exhibit monthly peak flow during spring and summer due to snow and ice melt. Lowland rivers have summer low flow months due to evapotranspiration.[3]

Electricity sector overview

The main sources of electricity in Switzerland are hydropower and nuclear power, respectively accounting for 59 per cent and 32.8 per cent of the total production, which amounted to 61.6 TWh in 2016 (including 2.9 TWh of pumping).[3] Production from thermal power plants accounts for 3.1 per cent of the total power production, while the remaining 5.1 per cent comes from other renewable sources (biomass, wind, biogas, photovoltaic) (Figure 1). The total consumption summed up to 62.6 TWh in 2016 (including 4.4 TWh of transmission and distribution losses). The electricity consumption remained stable in recent years, with efficiency gains offsetting positively the increase in demography and electrical household heating. However, winter electricity supply depends on import (5,047 GWh in 2016, between 2,000 and 4,000 GWh per winter semester in the past 11 years). Over the last consolidated year of statistics (2016),[3] hydropower was produced 41.5 per cent in winter and 58.5 per cent in the summer semester.

In 2011 Switzerland decided to gradually withdraw from the use of nuclear energy. Consequently, a long-term energy policy (termed Energy Strategy 2050) was outlined to guarantee a secure electricity supply.[8, 9] In September 2016 the Parliament accepted formally a first set of measures of this strategy, confirmed by universal referendum in May 2017. The strategy focuses on increasing the energy efficiency, expanding renewable energy use, undertaking an active foreign energy policy and, where necessary, electricity imports and/or local production from fossil fuels. Renovation and expansion of the grid infrastructure is also among the objectives of the strategy.

Figure 1.
Annual electricity generation by source in Switzerland (TWh)



Source: Swiss Federal Office for Energy (2017)[3]

Note: Data from 2016.

Currently, 643 hydropower plants with a capacity of at least 300 kW operate in Switzerland.[3, 4, 5, 6] A 48.2 per cent share of the hydropower production comes from run-of-river plants, 47.5 per cent from storage plants and 4.3 per cent from pumped-storage plants.

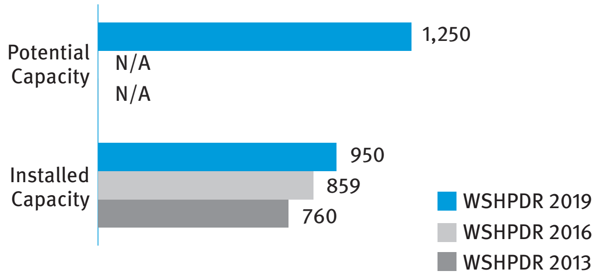
The Energy Strategy 2050 foresees an increase of hydropower efficiency and new production up to 1,500 GWh (or 3,200 GWh under optimal economic and social conditions). New pumping stations should help increase the energy storage and integration of solar and wind plants. Winter supply and operation flexibility remain the main challenges. At the end of 2016, the cumulated capacity of hydropower plants under construction was 1,477 MW, of which 1,400 MW were reversible pump-turbines. These plants will add a net 300 GWh/y to the national electricity generation.

The importance of other renewable sources in the Swiss energy mix is slowly increasing following progressive steps towards the nuclear phase out. The deployment of gas plants and imports of cheap electricity from foreign coal-fired plants are the available solutions for insuring the electricity supply. Incentives for the deployment of renewables such as small hydropower, solar, wind and biomass exist in multiple forms. These incentives are regularly revised to account for increased technology maturity and reduced deployment costs. Wind and small hydropower face significant opposition by local stakeholders in densely occupied areas of the territory. Geothermal plants face not only public opposition due to fears of induced-seismicity but still struggle to develop the cost-effective technical solutions needed for a viable business plan.

Small hydropower sector overview

In Switzerland, small hydropower refers to plants with an “annual average used” capacity up to 10 MW.[6] As of 2016 and following a detailed inventory, approximately 1,690 small hydropower plants were in operation in the country (of which 457 plants had capacities between 300 kW and 10 MW), with overall installed capacity of approximately 950 MW (of which 872 MW between 300 kW and 10 MW) and annual production of approximately 4,006 GWh (of which 3,641 GWh between 300 kW and 10 MW) (Figure 2). [5,13] This represents roughly 6 per cent of the national electricity production and 12 per cent of the total hydropower share. Among these small plants, an estimated seven hundred have installed capacity below 300 kW and account for only 1 per cent of the hydropower production. This group represents the remaining of a high number of small installations (about 7,000) operating in Switzerland at the beginning of the 20th century, which could be refurbished and contribute to the growth of small hydroelectricity production. However, the best sites are already used (in fact, as of April 2017, 554 plants with a total installed capacity of 393 MW benefit from feed-in-tariffs, producing on average 1,446 GWh/year).[7] Exploiting the remaining potential is under debate (from economic and ecologic perspectives).

Figure 2.
Small hydropower capacities 2013/2016/2019 in Switzerland (MW)



Source: *WSHPDR 2013*,[14] *WSHPDR 2016*,[15] Swiss Federal Office of Energy,[5] Swiss Federal Office of Energy[9]

Note: The comparison is between data from *WSHPDR 2013*, *WSHPDR 2016* and *WSHPDR 2019*.

Note: Installed SHP capacity of *WSHPDR 2019* includes estimation for plants up to 300 kW.

New technologies are under development to harvest hydraulic energy of existing infrastructure (e.g. fresh and wastewater networks, tailrace channels). Such plants benefit from good social acceptance. The federal authorities are sponsoring the required engineering developments (e.g. of new turbines) under the Hydropower Research Programme managed by the Federal Office of Energy.

The Energy Strategy 2050 indicates an available potential for small-scale hydropower up to 1,300 GWh/year in present conditions (approx. 250 MW), which may even increase to 1,600 GWh/year (approx. 300 MW), if design and implementation practices are improved and social acceptance increased.[9]

Renewable energy policy

The Swiss energy policy is defined by the energy and water articles in the Federal Constitution and detailed in the Acts on Energy, on CO_2, on Nuclear Energy, on Electricity Supply, on Waters Protection, on Hydropower, on Hydraulic Engineering and Spatial planning.[8] In particular, the Energy Act defines the regulatory framework for renewable energy, while the Water Protection and Hydropower Acts intervene in the field of hydropower operation. Other relevant regulations are the Fishery Act, the Spatial Planning Act, the Environmental and Forestry Protection Acts and the Nature and Cultural Heritage Act.

The Energy Strategy 2050 is a milestone of Swiss energy policies.[9] As aforementioned, this strategy focuses on the exploitation of energy potential from increased energy efficiency, hydropower and new renewable energy sources. The Swiss Energy Programme is the instrument specifically developed to implement the energy and climate objectives of the Federal government and the cantons. In particular, cantons determine strategies for the building sector, sustainable energy supply, energy planning and energy-efficient mobility, and promote efficient use of the energy and of the waste heat by means of financial incentives. The Renewable Energy Action

Plan sets targets on growth of renewable energy production.

The Federal Government promotes electricity production from renewable energy sources through two main economic instruments: feed-in remuneration at cost and one-off investment grants.[10] The feed-in tariff at cost bridges the gap between market price and cost borne by producers of electricity from renewable sources. This tariff is available for hydropower plants (up to an annual-average capacity of 10 MW), photovoltaics (starting from an installed capacity of 10 kW), wind and geothermal energy, biomass and biological waste, and is applicable for 20 years (10 years for biomass power plants). For existing facilities, previous investments in water conveyance (e.g. intake works, waterways and penstocks) are eligible for a tariff bonus if carried out in the past 20 years, promoting good asset management. Tariff rates are regularly reviewed to consider technological progress and increasing maturity of new technologies. The reviewed tariffs only apply to new production facilities. One-off investment grants, instead, aim to foster electricity production in small photovoltaic systems (from 2 up to 30 kW) by subsidizing a maximum of 30 per cent of the investment costs. In addition to the described mechanisms of financial support, non-financial measures have been set in the Energy Act, such as priority dispatch (i.e. supply companies must purchase electricity from independent producers).

Economic and social/environmental barriers for the development of small-scale hydropower are effectively addressed in Switzerland, e.g. through the cost-based feed-in tariff and the involvement of communities in establishing rivers that will be affected by plant operation. A water platform promoting dialogue among stakeholders also exists, and research efforts aimed to address rising questions receive support from the Federal authorities. Additional barriers result from the complex regulatory context imposed by today's societal view on natural values and resources, which for small hydropower involve complying with legislation on water and energy, environment and development planning, at federal, cantonal and municipal levels. The Energy Strategy 2050 tries to address these issues by simplifying and harmonizing administrative procedures throughout the whole country. Examples of needed interventions are the establishment of a single contact point for small hydropower plants (where not yet available), a checklist for projects promoters, the possibility to group applications for several installations along the same river and the expansion of the Hydropower Research Programme of the Swiss Federal Office for Energy.[11]

Barriers to small hydropower development

In general, small hydropower is providing a sound contribution to Swiss society. The development of new small hydropower projects is hampered mainly by:

- Conflicts with other water uses/rights in densely populated (lowland) areas, including with new river restoration projects of impaired river reaches as required by the Waters Protection Act.
- Difficulties to come up with appropriate and cost-effective solutions for accessing electricity transmission lines for greenfield projects in natural creeks. The social perception that individual small plants have unsubstantial contribution to large societal needs (e.g. energy transition targets), raises public concern regarding local and cumulated ecologic impact on small pristine rivers.
- Poorly engineered projects, with reduced teams with limited skills, often lead to the overestimation of the production and underestimation of costs.[12] Improvement of engineering design of small schemes (often overlooked due to the associated high cost per kWh) and introduction of environmentally friendly solutions in new and existing facilities are required in order to enhance public acceptance. Improved engineering design should focus on properly sized facilities based on the available water resources and site conditions, as well as on innovative management and environmental flow rules. The ecologic as well as technical and economic feasibilities must be assessed from early project phases, which implies mobilizing skilled engineering teams (more costly than 'jacks-of-all-trades'), to reduce the uncertainty of water availability and potential energy production, as well as investment costs, which often are poorly addressed at early stages. This request for properly sized, high quality and eco-balanced projects is leading to a natural selection of viable projects. Following the approval of the new energy transition law, the new ordinance (in force since January 2018) limits incentives to a minimum power of 1 MW in fluvial system, or 300 kW for rehabilitation projects, except for any synergetic projects with other industrial water uses that have no direct impact with the natural or high-ecological interest river reaches.
- Excessive production of legal and regulatory documents: despite the stable legal framework (updates done in general every 20 years), the operational directives and the financial incentive mechanisms tend to change in shorter timeframes. This reflects the interplay between the different competing renewable energy technologies and their marginal interest but hampers developers from engaging in projects. Synergetic projects where hydropower is one among other sources (e.g. solar, water supply, drought-support, ecological restoration) tend to find better ground with authorities, public opinion and funding partners than stand-alone small hydropower projects.

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Contributing organizations

Laboratoire de Génie Électrique d'Oran (LGEO)

Université des sciences et de la technologie d'Oran – Mohamed Boudiaf (USTO-MB)

Guakía Ambiente

Scientific Research Institute of Energy (SRIE)

Kleinwasserkraft Österreich

Pöyry

Jimma University

France Hydro Électricité

Ea Energy Analyses

Guyana Energy Agency (GEA)

La Asociación Hondureña de Energía Renovable (AHER)

The International Energy Agency Technology Cooperation Programme on Hydropower (IEA Hydro)

International Network on Small Hydro Power (INSHP)

Komite Nasional Indonesia untuk Bendungan Besar (KNI-BB) / National Committee on Large Dams (INACOLD)

Catalytic Innovations

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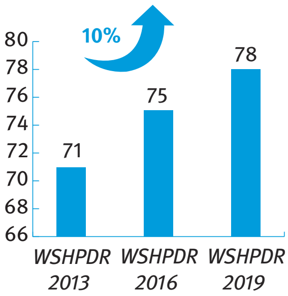
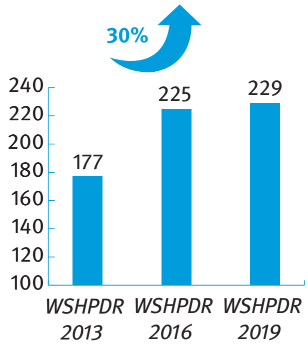
World Small Hydropower Development Report 2019

The ***World Small Hydropower Development Report (WSHPDR) 2019*** is an update of the Report's first two editions in 2013 and 2016. The *WSHPDR 2019* contains 166 national reports and 20 regional reports, with 21 new countries added since the first edition.

World SHP installed capacity (GW)



World SHP potential (GW)



- The Report is available on **www.smallhydroworld.org;**
- More than 230 experts and organizations have been involved;
- The Report covers **20 regions and 166 countries**;
- Every country report provides information on:
  a) Electricity sector;
  b) Small hydropower sector;
  c) Renewable energy policy and;
  d) Barriers to small hydropower development.

A special report with **Case Studies** is added to the *WSHPDR 2019*, showing the different roles small hydropower can play in achieving the SDGs.

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